PB-228 945

A STUDY OF THE POLLUTION AND NATURAL PURIFICATION OF THE ILLINOIS RIVER.
I. SURVEYS AND LABORATORY STUDIES

J. K. Hoskins, et al

Public Health Service
Washington, D. C.

May 1927

DISTRIBUTED BY:

NTIS
National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

PB 228 945

X171

PUBLIC HEALTH BULLETIN

No. 171

A STUDY OF THE POLLUTION AND NATURAL PURIFICATION OF THE ILLINOIS RIVER

I. SURVEYS AND LABORATORY STUDIES

LIBRARY COPY

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

TREASURY DEPARTMENT
STATES PUBLIC HEALTH SERVICE
WASHINGTON, D. C.
1927

FS 2.6
X171

LIBRARY
[illegible]
[illegible]

239

TREASURY DEPARTMENT
UNITED STATES PUBLIC HEALTH SERVICE

PUBLIC HEALTH BULLETIN No. 171
MAY, 1927

A STUDY OF THE POLLUTION AND NATURAL PURIFICATION OF THE ILLINOIS RIVER

I. SURVEYS AND LABORATORY STUDIES

BY

J. K. HOSKINS, Sanitary Engineer
C. C. RUCHHOFT, Junior Chemist
L. G. WILLIAMS, Junior Assistant Sanitary Engineer

PREPARED BY DIRECTION OF THE SURGEON GENERAL

II - FSv.6 + 198

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON
1927

LIBRARY
DEPT. OF THE INTERIOR, FWPCA
METUCHEN, N. J. 08840

PERSONNEL OF STREAM POLLUTION INVESTIGATIONS, UNITED STATES PUBLIC HEALTH SERVICE, ILLINOIS RIVER INVESTIGATION

Surg. W. H. FROST, in charge, stream pollution investigations

CONSULTANTS

Dr. STEPHEN A. FORBES, director Illinois State Natural History Survey.
Dr. EDWIN O. JORDAN, professor of bacteriology, University of Chicago.
Mr. LANGDON PEARSE, sanitary engineer, Sanitary District of Chicago.

SCIENTIFIC PERSONNEL

Sanitary Engineer J. K. HOSKINS, in charge, Illinois River investigation.
Sanitary Engineer H. W. STREETER, Joliet branch laboratory.
Bacteriologist C. T. BUTTERFIELD.
Chemist E. J. THERIAULT.
Junior Assistant Sanitary Engineer L. G. WILLIAMS.
Junior Chemist C. C. RUCHHOFT.
Sanitary Bacteriologist R. E. NOBLE.

TECHNICIANS

ELIZABETH ARENTZ.
ROCKWELL BARNETT.
WILLIAM R. DOUGLAS.
A. L. GOOGINS.
MABEL G. MASTEN.

CONTENTS

Page

Introduction — XI

Chapter I. Features of the Illinois River and its watershed — 1
- Physical features — 1
- Geological history — 1
- The main drainage canal — 2
- The Illinois River system — 4
- The present river channel — 6

Chapter II. Population of the Illinois River watershed, and sources of pollution of the river — 12
- Population — 12
  - Sewage pollution — 16
  - Sewage treatment — 18
- Pollution due to industrial wastes — 19

Chapter III. Hydrometric measurements — 27
- Purpose of hydrometric studies — 27
- Data from which calculations were made — 27
  - Maps — 27
  - Gauge heights — 28
  - Rating stations — 30
- Methods of calculating discharge — 32
  - Discharges of rated tributaries — 32
  - Discharges of unrated tributaries — 33
  - Rates of discharge at sampling stations — 33
  - Discharges at sampling stations above Peoria — 36
  - Discharges at sampling stations below Peoria — 40
- Time of flow between sampling stations — 45

Chapter IV. Methods of procedure in field and laboratory studies — 51
- Selection of sampling stations on the main stream — 51
- Sampling stations on principal tributaries — 55
- Collection of water samples — 57
- Delivery of samples — 60
- Chemical methods — 61
  - Turbidity — 61
  - Alkalinity — 61
  - Dissolved oxygen — 61
  - Oxygen demand — 63
  - Suspended matter — 63
- Methods of analysis of sanitary chemical samples — 64
- Bacteriological methods — 64
  - Culture media — 65
  - Apparatus — 67
  - Determination of total counts — 67
  - Determination of *B. coli* — 69
    - a. Presumptive and partially confirmed test — 69
    - b. Completely confirmed test — 70
  - Differentiation of fecal and nonfecal types of *B. coli* — 70

Page
Chapter V. Sanitary chemical analyses 72
- Presentation of data 72
- Discussion 99
  - Intensity of pollution in the main drainage canal 99
  - Per capita contribution of polluting constituents 103
  - Seasonal variations in the chemical constituents of the Illinois River 104
- Comparison with results of previous investigations 107

Chapter VI. Bacteriological studies 113
- Presentation of data 113
- Bacterial pollution of the Illinois River 158
- Relation between gelatin, agar, and *B. coli* counts 159
  - Ratio of 20° gelatin to 37° agar counts 159
  - Ratio of 20° gelatin count to *B. coli* 160
  - Ratio of 37° agar count to *B. coli* 162
- Seasonal changes in bacterial concentration 162
- Relation of bacterial pollution to sewered population contributing 163
- Natural purification 165
- Upper Illinois River 166
  - Variations in volume and concentration of flow of main drainage canal 170
  - Rates of natural purification 179
  - The average rates of purification defined by curves 186
- Lower Illinois River 189
  - Curves defining average rates of purification 192
- Comparison of derived curves of purification rates with those of the Ohio River 193
- General summary 196

Appendix A:

- Relation of various datum planes of the Mississippi River Valley 201

Appendix B:

- Preservation of samples for sanitary chemical analysis 202
  - Efficacy of acidification as a method of preservation 203
  - Precision attainable in sanitary chemical analysis 208

LIST OF TABLES

CHAPTER I

Page
1. Variations in bed of upper Illinois River 5
2. Principal tributaries of the Illinois River 6
3. Dams in the Illinois River and Chicago Sanitary Canal 8
4. Location of cities, towns, bridges, gauges, sampling stations, etc., on the Illinois River 9

CHAPTER II

5. Population of the Illinois River drainage basin by tributary watersheds 15
6. Drainage areas and total population above various points on the Illinois River 16
7. Sewered population by 50-mile zones above each sampling point on the Illinois River 17
8. Sewered population on tributary watersheds of the Illinois River by 50-mile zones from their mouths 17
9. Estimated average amounts of certain constituents contained in industrial wastes from various industries per unit of raw material or product 20
10. Record of animals slaughtered at Chicago, June, 1921, to August, 1922, inclusive 23
11. Derivation of population equivalent of packingtown wastes 23
12. Population equivalent of Chicago sewage and industrial wastes 24
13. Summary of actual sewered population on Illinois River watershed, with estimates of population equivalents of industrial wastes 25

CHAPTER III

14. Summarized description of Illinois River prisms 29
15. Relative location of principal tributaries of the Illinois River and their respective rating stations 30
16. Monthly average rates of discharge in cubic feet per second of Illinois River tributaries at their mouths 32
17. Smaller tributaries of the Illinois River 33
18. Discharge and time of flow computations 34
19. Monthly average discharge in cubic feet per second of the Illinois River at the various sampling stations 42
20. Analysis of monthly average rates of discharge at certain sampling stations of the Illinois River 44
21. Monthly mean time of flow in hours from station 286 to each sampling station 49
22. Seasonal average times of flow in hours from station 292 to successive sampling stations to station 166, inclusive, and from station 148 to station 26, inclusive 50

CHAPTER IV

23. Location of sampling stations along main river channel together with physical features of the stream above and below sampling points 53
24. Data relative to the collection and transportation of samples 60

CHAPTER V

Page

25. Summary of monthly averages results of sanitary chemical analyses for each sampling station, arranged by months 74
26. Summary of monthly average results of sanitary chemical analyses for each constituent, expressed in parts per million, arranged by sampling stations and months 85
27. Summary of monthly average results of sanitary chemical analyses for each constituent, expressed in quantity units, arranged by sampling stations and months 87
28. Summary of monthly average results of sanitary chemical analyses for each constituent of the upper Illinois River, expressed in quantity units, with contributions by tributaries deducted 93
29. Yearly and seasonal average sanitary chemical analyses of Illinois River and tributaries, expressed in parts per million 96
30. Yearly and seasonal average sanitary chemical analyses of Illinois River and tributaries, both observed and corrected, expressed in quantity units 97
31. Monthly average amounts of suspended solids in samples from certain parts of the Illinois River 99
32. Base data pertaining to combined sewage 100
33. Relative pollution of main drainage canal at station 292, as compared with standard sewage 101
34. Relative pollution of main drainage canal at station 292, as compared with Chicago sewage 102
35. Analytical content of Lake Michigan water at Thirty-ninth Street, Chicago 102
36. Grams per capita contribution of polluting constituents to water of main drainage canal at Summit 103
37. Change in per capita amounts of organic constituents contributed by Chicago during time of passage from station 292 to station 166 104
38. Monthly average temperatures of the Illinois River at various sampling stations 105
39. Free ammonia results—yearly averages in parts per million 108
40. Organic nitrogen results—yearly averages in parts per million 109
41. Kjeldahl nitrogen results—yearly averages in parts per million 109
42. Nitrogen oxide results—yearly averages in parts per million 109
43. Total nitrogen results—yearly averages in parts per million 110
44. Oxygen consumed results—yearly averages in parts per million 110
45. Quantities of nitrogenous and oyxgen-consuming material discharged into the Illinois River at Chicago 111

CHAPTER VI

46. Summary of bacteriological observations and dissolved oxygen determinations by stations—monthly means at each station with corresponding means of discharge and related data 114
47. Summary of bacteriological observations and dissolved oxygen determinations by months—monthly means at all stations with corresponding means of discharge and related data 125
48. Summary of bacteriological observations by stations in terms of "quantity units" (bacteria per c. c. × discharge in thousands of second-feet)—monthly means and seasonal averages at each station 140

Page
49. Summary of bacteriological observations at all sampling stations in terms of quantity units (bacteria per c. c. × discharge in thousands of second-feet)—means for gelatin count, agar count and *B. coli*, respectively, for four seasonal periods 154
50. Comparison of bacterial content of main drainage canal with domestic sewage 158
51. Ratios of gelatin counts to agar counts (=1.0) at representative sampling stations on the Illinois River, by months, 1921–22 160
52. Ratios of gelatin counts to *B. coli* counts (=1.0) at representative sampling stations on the Illinois River, by months, 1921–22 161
53. Ratios of agar counts to *B. coli* counts (=1.0) at representative sampling stations of the Illinois River, by months, 1921–22 162
54. Seasonal variation in bacterial content 163
55. Seasonal fluctuation in quantity units of bacteria in Ohio and Illinois Rivers below major sources of pollution 163
56. Bacterial pollution (in quantity units) per capita in Illinois River, contributed to the main drainage canal and Illinois River 164
57. Seasonal changes in numbers of bacteria added to streams by sewered populations of Cincinnati, Louisville, Chicago, and Peoria 165
58. Estimated pollution added by principal cities along the upper Illinois River as measured by bacteria growing on agar at 37° C. and expressed in percentages of quantity units present in the stream at station next above 167
59. Derivation of correction factors for quantity units of bacteria added by tributaries and cities, Summer gelatin 169
60. Correction factors for observed quantity units of bacteria added by tributaries and cities 170
61. Average gauge height and discharge at station 288 171
62. Fluctuations in oxygen demand at station 292 at various times of day 171
63. Daily fluctuation in oxygen demand at station 288 174
64. Daily fluctuation in gelatin counts at station 288 175
65. Daily fluctuation in agar counts at station 288 175
66. Correction factors for variation of sewage strength and volume of flow 177
67. Quantity units of bacteria, agar counts, remaining at various sampling stations, observed and corrected values, with corresponding per cents of maximum 178
68. Summary of bacteriological observations at all sampling stations, upper Illinois River, corrected for tributary inflow and cities, with times of flow from point of maximum concentration 180
69. Bacteria remaining at various sampling stations, upper Illinois River, corrected for tributary inflow and cities, expressed in percentages of the maximum and with times of flow below this maximum 181
70. Coordinates of curves describing decrease in gelatin counts, agar counts and *B. coli*, in relation to time of flow from zone of maximum pollution—Upper Illinois River 187
71. Correction factors for observed quantity units of bacteria added by tributaries and cities 190
72. Summary of bacteriological observations at all sampling stations, lower Illinois River, corrected for tributary inflow and cities, with times of flow from point of maximum concentration 191
73. Bacteria remaining at various sampling stations, lower Illinois River, corrected for tributary inflow and cities, expressed in percentages of the maximum and with times of flow below this maximum 191

Page
74. Coordinates of curves, describing decrease in gelatin counts, agar counts, and *B. coli*, in relation to time of flow from zone of maximum pollution—lower Illinois River 193
75. Comparison of coordinates of bacterial purification rates, Illinois River and Ohio River, agar counts, summer season 194
76. Comparison of coordinates of bacterial purification curves, Illinois and Ohio Rivers, adjusted for equivalent concentrations 195

APPENDIX B

1. Changes in the chemical composition of samples stored 10 to 15 days days without the addition of any preservative 203
2. Constancy of the free ammonia content of acidified river water 204
3. Changes in the nitrite content of acidified river water 205
4. Constancy of the nitrogen oxide content of acidified river water 206
4a. Constancy of the nitrogen oxide content of acidified river water (using the slightly modified reduction method) 206
5. Constancy of the Kjeldahl nitrogen content of acidified river samples 207
6. Constancy of the permanganate oxygen consumed value of acidified river samples 208

LIST OF FIGURES

Chapter I

Page
1. Map of the Illinois River watershed 6
2. Profile of the Illinois River and the Chicago Drainage Canal 7

Chapter III

3. Hydrographs of gauge height and discharge of the Illinois River, July, 1921, to August, 1922 31
4. Specimen diagram of discharges at sampling stations above Peoria 38
5. Gauge height-area curve of prism No. 27 47
6. Profile of water surface of prisms Nos. 27 and 28 47

Chapter IV

7. Cross section of the Illinois River at sampling station 240, May 13, 1921 56
8. Sampling section at mile 240, Illinois River 56
9. Sample collector of galvanized iron 58
10. Laboratory sample shipping case 62

Chapter V

11. Quantity units of free ammonia at various sampling stations of the upper Illinois River, both observed and as corrected for amounts added by tributaries 106
12. Quantity units of nitrogen oxides at various sampling stations of the upper Illinois River, both observed and as corrected for amounts added by tributaries 106
13. Quantity units of Kjeldahl nitrogen at various sampling stations of the upper Illinois River, both observed and as corrected for amounts added by tributaries 107
14. Quantity units of organic nitrogen at various sampling stations of the upper Illinois River, both observed and as corrected for amounts added by tributaries 107
15. Quantity units of total nitrogen at various sampling stations of the upper Illinois River, both observed and as corrected for amounts added by tributaries 107
16. Quantity units of oxygen consumed at various sampling stations of the upper Illinois River, both observed and as corrected for amounts added by tributaries 107

Chapter VI

17. Fluctuation in daily gauge height at station 288, summer and winter seasons 172
18. Fluctuation in oxygen demand at station 292 throughout the day 173
19. Fluctuations at station 288 of oxygen demand and bacterial counts, in terms of 24-hour average, compared with fluctuation in oxygen demand at station 292 174

Page
20. Fluctuation in volume of flow at station 292 176
21. Rates of decrease in agar counts, upper Illinois River, summer season 182
22. Rates of decrease in agar counts, upper Illinois River, winter season 184
23. Rates of decrease in agar counts, upper Illinois River, winter transitional and summer transitional seasons 185
24. Bacterial purification in the upper Illinois River in relation to time of flow from zone of maximum pollution. Gelatin counts, summer and winter months 186
25. Bacterial purification in the upper Illinois River in relation to time of flow from zone of maximum pollution. Agar counts, summer and winter months 186
26. Bacterial purification in the upper Illinois River in relation to time of flow from zone of maximum pollution. *B. coli* determinations, summer and winter months 186
27. Bacterial purification in the upper Illinois River in relation to time of flow from zone of maximum pollution. Gelatin counts, summer transitional and winter transitional seasons 186
28. Bacterial purification in the upper Illinois River in relation to time of flow from zone of maximum pollution. Agar counts, summer transitional and winter transitional seasons 186
29. Bacterial purification in the upper Illinois River in relation to time of flow from zone of maximum pollution. *B. coli* determinations, summer transitional and winter transitional seasons 186
30. Bacterial purification in the lower Illinois River in relation to time of flow from zone of maximum pollution. Gelatin counts, summer, winter, summer transitional, and winter transitional seasons 192
31. Bacterial purification in the lower Illinois River in relation to time of flow from zone of maximum pollution. Agar counts, summer, winter, summer transitional, and winter transitional seasons 192
32. Bacterial purification in the lower Illinois River in relation to time of flow from zone of maximum pollution. *B. coli* determinations, summer, winter, summer transitional, and winter transitional seasons 192
33. Comparison of rates of bacterial purification in the Ohio, upper Illinois, and lower Illinois Rivers in relation to time of flow from zones of maximum pollution. Agar counts, summer and winter seasons 194
34. Comparison of rates of bacterial purification in the Ohio, upper Illinois, and lower Illinois Rivers, in relation to time of flow from zones of equal concentration. Agar counts, summer months, and *B. coli* determinations, summer months 194
35. Comparison of rates of bacterial purification in the Ohio, upper Illinois, and lower Illinois Rivers, in relation to time of flow from zones of equal concentration. Agar counts, winter months, and gelatin counts, summer months 195

INTRODUCTION

The United States Public Health Service has been engaged in studies of the pollution of inland streams for a number of years. These investigations have of necessity covered a considerable range of subjects because of the inherent relationships of various phases of the problem. Stream pollution, on the one hand, is closely connected with the problem of public water supply and the efficiency of systems for satisfactory water purification, and, on the other hand, with the best methods for the prompt and effective disposal of domestic sewage and industrial wastes. Both of these phases of the problem are of equal significance from the standpoint of public health, and indeed may exceed in importance the matter of actual condition of the stream itself resulting from excessive pollution. The broad objectives of the studies have therefore been:

1. To develop practical procedures for the measurement of stream pollution and suitable forms for expression of the degree of pollution encountered.

2. To ascertain the probable effects to be anticipated from increasing pollution loads and to determine the power of streams to recover from such imposed burdens, through the operation of natural agencies.

3. To observe the effects of stream pollution on the public health, as reflected in the quality of water supplies, procurable from polluted sources and as influenced by methods of removal and disposal of domestic sewage and industrial wastes.

The studies discussed in the present report are primarily concerned with the second of these objectives, in the development of which, use has necessarily been made of the procedures mentioned in the first.

The Illinois River was selected for intensive study for several practical reasons. The stream, approximately 300 miles in length, is excessively polluted at its source by the sewage flow of the greater part of the city of Chicago. Comparatively small amounts of additional pollution are added throughout its further course, so that this river is peculiarly adapted to a study of the natural agencies active in stream purification.

Previous studies of the extent and effect of this pollution made by other agencies such as the Illinois State Natural History Survey, the Illinois State Board of Health, and the Sanitary District of Chicago, while conducted from somewhat different angles, had assembled a large amount of pertinent data of great value which, being available, greatly reduced the preliminary work necessary for the inauguration of a field study of this nature. Moreover, the

Sanitary District of Chicago, being directly interested in the condition of the river because of the increasing pollution caused by the sewage discharge of the city, was willing to cooperate in an intensive study to determine the degree of natural purification being effected. Other State governmental agencies were likewise in position to render appreciable assistance in the conduct of the field survey.

The general procedure followed in the present study has been to obtain definite knowledge of the physical and hydrographic features of the stream and to correlate these characteristics with observations on the condition of the river water as determined by chemical, bacteriological, and biological analyses. Such analyses were made of samples collected from fixed sampling stations, established at points throughout the stream length, and were continued over sufficient periods of time to indicate the seasonal and other changes likely to occur as well as to be thoroughly representative of general conditions existing.

For the conduct of the field and laboratory work, headquarters were established in Peoria, Ill., and branch laboratories located at accessible points along the stream, at Joilet, Beardstown, and Kampsville. Laboratory analyses were first started at Peoria on April 11, 1921, and, after all laboratories were in operation, continued without interruption until September 1, 1922, when the field work was discontinued.

In this report are presented such data on the physical features of the watershed as are essential to a study of pollution; a summary of sources of pollution and calculations of stream flow and time intervals. The basic data of the findings in bacteriological and chemical examinations are given in several series of tables condensed into the form of monthly averages. A discussion of the salient features of these results is also included. More detailed discussions of other features of the investigation are being prepared to appear in later publications of the service.[1]

It is desired to acknowledge the assistance rendered by various organizations and persons, during the course of the work and in the preparation of this report. Special acknowledgment is due the Sanitary District of Chicago for the continued interest and cooperation maintained throughout the period of the study, without which efficient conduct of the investigation would have been impossible. Individual acknowledgments are made to Mr. Langdon Pearse, sanitary engineer, and Dr. F. W. Mohlman, chemist, both of the Sanitary District of Chicago, for valued assistance at all times and for helpful criticism of the manuscript. The State Natural History Survey of Illinois, under the direction of Prof. Stephen A. Forbes, has rendered material service more especially in connection with the biological studies. The State Department of Health of Illinois, the Illinois State Water Survey, the State Board of Health of Indiana, and the State Board of Health of Wisconsin have supplied important data. In the detailed preparation of base data contained in this report and in methods of its presentation, the personnel of stream pollution investigations has rendered much valuable assistance, especially Chemist E. J. Theriault and Bacteriologist C. T. Butterfield, in connection with Chapters IV and V. Surg. W. H. Frost has collaborated in the treatment of the bacteriological data of Chapter VI, and has been closely associated with the studies herein recorded from their inception.

---

[1] A report upon studies of the plankton has been prepared and will appear shortly.

CHAPTER I

FEATURES OF THE ILLINOIS RIVER AND ITS WATERSHED

PHYSICAL FEATURES

The watershed of the Illinois River extends in a belt approximately 100 miles wide and 260 miles long diagonally across the upper half of the State of Illinois from northeast to southwest. The upper part of this area is divided or split by the intrusion of Lake Michigan. The right, or eastern arm, extends into the State of Indiana, having a width of 60 to 80 miles, and is drained by the Kankakee River, while the left, or northern arm, having a width of 20 to 40 miles, reaches into southern Wisconsin and forms the watersheds of the Fox and Des Plaines Rivers. Practically all the watershed area lies in the rather flat plain of the eastern central Mississippi drainage basin, in which abrupt changes in surface elevation are not marked. The drainage slopes, especially to the north and east, are flat and in many cases so slight that extensive swamp lands are formed. This is particularly true of a considerable area of the watershed lying in the State of Indiana. The southern parts of the watershed are more rolling.

The natural watershed of the Illinois has been artificially increased by the construction of the main drainage canal of the Sanitary District of Chicago, which cuts through the low divide between the Des Plaines, a tributary of the Illinois River, and the Chicago River, tributary to Lake Michigan, thereby reversing the flow of the latter stream and causing it to flow into the Des Plaines. The total area comprised within the basin, including the 217 square miles added by the drainage canal, is 28,344 square miles. Of this area, 2,137 square miles are in Indiana, 993 in Wisconsin, and the remainder, or 24,214 square miles, in the State of Illinois.

GEOLOGICAL HISTORY

The early geological history and development of the Illinois drainage basin is identical with that of the larger part of the upper Mississippi Valley, of which it forms a part. The successive periods of submergence and elevation of the area below and above the line of the Mississippi Sea resulted in deposition of the materials forming the underlying strata of the basin, including the coal measures. These uneven fluctuations in land levels resulted in many changes in the drainage system. Old, well-established river channels became useless or entirely too large for the diminished flow resulting from the changing land elevation. Later the great glacial invasions made profound changes in this entire area, filling up existing river valleys to the depth of hundreds of feet with material transported by the powerful force of the moving ice sheets, which advanced and receded several times. These ice movements resulted in the deposition of immense masses of earth and rock debris in the form of terminal moraines, which mark the limits of advance of the ice. The water from the melting ice mountains spread this and finer material, known as "drift," over the area far beyond the ice front. The entire watershed of the present Illinois River is covered with this drift, capped in many places by loess, a finer material probably deposited by wind action.

The waters from the melting glaciers were dammed between the northward retreating ice walls and the sloping moraines, forming lakes, among which was the glacial Lake Chicago, which was held in the southern end of the Lake Michigan Basin. These immense and increasing volumes of water were forced to seek outlets through the glacial drift and, frequently following the rather obscure preglacial channels, cut down and eroded new channels for drainage. Such a channel was the Chicago outlet of the glacial Lake Chicago. As the ice retreated farther north other eastern outlets, including the St. Lawrence, were made available, with the result that the flow through the Chicago outlet was greatly diminished in volume and finally ceased altogether.

The Chicago outlet had two points of discharge from the lake to the Des Plaines, the one entering at Summit and the other at Sag Bridge, both of which shifted with the fluctuating water levels of Lake Chicago. The outlet has a width varying from 1 to 5 miles and a depth of from 20 to 70 feet. With the exception of about 15 miles between Lemont and Joliet and 40 miles between Morris and Peru, where rock strata have been eroded, the excavation is almost entirely in beds of drift. The width varies with resistance to erosion and is also in some degree dependent upon the slope of the land.

The portion of the Illinois Basin below Hennepin is a preglacial valley and was only partly filled by the glacial deposits, while above Hennepin the stream runs mainly in a glacial or postglacial course.

The prevailing soil of the watershed is a rich, black loam (loess), ranging in thickness from 1 to 4 feet and constituting a very fertile agricultural plain. The top soil is generally underlain by the glacial drift of bowlder clay. Artificial drainage by ditching and tile has generally enhanced the tillable value of much of the area.

THE MAIN DRAINAGE CANAL

The city of Chicago is located at the mouth of the Chicago River, along the southwestern shore of Lake Michigan, from which latter source it derives its water supply and into which its sewage and drainage were formerly discharged. To improve the highly insanitary conditions resulting from this method of sewage disposal, the Sanitary District of Chicago, embracing the city of Chicago and a considerable contiguous area, was granted a charter in 1889 for the purpose of providing "for the disposal of sewage of the district by dilution and outlet into the Illinois River and to provide such other sewage disposal as shall preclude the contamination of Lake Michigan water supply."[3] In pursuance of this purpose a drainage canal was excavated through the divide separating the drainage areas of the Chicago and Illinois Rivers and at such a gradient that the flow of the Chicago River was reversed, water entering from Lake Michigan and, together with the sewage of the Sanitary District, flowing through the canal to the Des Plaines River at Lockport. The canal proper, which was placed in operation January 2, 1900, starts at the west fork of the South Branch of the Chicago River, near Robey Street, and extends in a southwesterly direction for a distance of approximately 28 miles. The channel is from 160 to 200 feet wide, is approximately 26 feet deep throughout its entire length, and has a capacity of approximately 14,000 second-feet, but, owing to various restrictions, the average flow has been considerably less than this amount. Control works were constructed at the lower end to regulate the flow through the channel. Later the channel was extended and a power house constructed just above Joliet to utilize the available head of 34 feet existing between the end of the canal and the Des Plaines River.

Additional supplementary works have been undertaken to utilize to the best advantage the artificial drainage system thus provided. The South Branch of the Chicago River from Robey Street to Lake Street (the point of junction with the North Branch to form the main Chicago River), a distance of 5 miles, was widened to 200 feet and deepened to 26 feet by the Sanitary District of Chicago. The United States likewise improved the channel of the main river from Lake Street to its mouth at Lake Michigan, so that the entire waterway from Lake Michigan to Joliet has been developed. Tributary channels have also been improved or provided to facilitate the drainage of the Sanitary District area. Such works include the creation of a second intake channel from Lake Michigan, effected by widening and deepening the North Branch of the Chicago River to Lawrence Avenue, and constructing from this point the North Shore Channel, a distance of 8 miles, to Lake Michigan at Wilmette. A third outlet from the lake, the Calumet Sag Channel, 16 miles long, connecting the Little Calumet River near Blue Island with the main drainage canal at Sag, was not completed at the time of this investigation.

---

[3] Engineering Data on the Sanitary District of Chicago. Published by the district, October, 1920.

The lengths of the principal drainage channels thus provided are:

	Miles
Main drainage canal:	
Chicago River from mouth to Lake Street	0.9
South Branch from Lake Street to Robey Street	5.0
Main channel from Robey Street to Lockport control works	28.0
Main channel extension from Lockport to power house	2.1
North Shore Channel:	
From Lake Michigan at Wilmette to North Branch at Lawrence Street	8.14
North Branch of the Chicago River from Lawrence Street to Belmont Avenue	2.2
Belmont Avenue to Lake Street (junction with South Branch)	4.8

In addition to these main drainage channels, auxiliary works have been constructed such as pumping stations, intercepting sewers, and alterations or improvements in the sewerage system to conduct properly the sewage of the district to the main drainage canal.

The result of the discharge from this canal has been to increase greatly the volume of flow throughout the length of the Illinois River and to pollute very seriously the stream with the sewage and wastes of the city of Chicago.

THE ILLINOIS RIVER SYSTEM

The Illinois River proper is formed by the confluence of the Kankakee and Des Plaines Rivers, which serve the eastern and part of the northernmost sections of the drainage area, respectively. From this junction point, 12 miles below Joliet, the river flows a distance of 273 miles, first flowing for 62 miles almost directly west and then, changing direction suddenly at the great bend at Hennepin, flowing southwest to join the Mississippi 20 miles above the mouth of the Missouri and 35 miles above St. Louis. The river lies for the most part near the western border of its watershed, so that, as a rule, the largest tributaries approach from the east.

The main volume of flow is through the main drainage canal which joins the Des Plaines just above Joliet, thence continuing through the Des Plaines to the junction with the Kankakee and then through the channel of the Illinois River. For convenience of expression in this report, however, the principal line of flow, starting from the outlet of the main drainage canal and extending to the mouth of the Illinois River at Grafton, is included in the name "Illinois River," while the mouth of the Des Plaines River is assumed to be at the point of confluence with the sanitary canal above Joliet.

The Illinois Valley is naturally divided into an upper and a lower part. The upper Illinois, comprising the westward-flowing section from the junction of the Des Plaines and Kankakee to the great bend near Hennepin, is independent of preglacial drainage lines and is excavating a new course, its bed being usually on the rock. The lower Illinois, extending from the great bend to the mouth, occupies the preglacial channel, in which the rock bottom lies nearly 100 feet below the bed of the present stream.

The upper Illinois, in the first 41 miles of its course, has a rapid though irregular descent through a series of rock channels separated by pools, as shown in the following table by Leverett:[3]

TABLE No. 1.—*Variations in bed of upper Illinois River*

	Distance	Low water (above tide)	Fall per mile
	Miles	*Feet*	*Inches*
Mouth of Kankakee River	0	485.3	
One mile below	1	481.6	44.04
Head of Marseilles pool	11.7	477.9	3.80
Marseilles, below dam	12.7	468.9	8.50
Foot of Marseilles Rapids	1.5	458.3	84.60
Mouth of Fox River	5.3	447.9	23.54
Head of rapids	6.7	444.9	5.37
Foot of rapids, near Utica	2.6	438.1	31.38

The old river channel of the lower Illinois is much too large for the present volume of flow, so that it has been filled up by alluvial deposits forming the present bottom lands. The deposition of material has also been aided by the flat slope of the stream, the fall in the lower 223 miles being only 33 feet. The bottom lands of the lower river are well described by Alvord and Burdick.[4]

> As in the upper river, the bottoms are flanked by bluffs or hills, but the flood plain is wider, ranging from 1½ miles to 3 miles above Peoria, 3 to 5 miles near Havana, and 6 to 7 miles near Beardstown, at the mouth of the Sangamon River. In the lower 60 miles, the bottom lands are generally 3 to 4 miles in width. From La Salle to the Mississippi, the bottom land subject to flood aggregates about 400,000 acres, or 620 square miles. The immediate banks of the stream are nearly everywhere higher than the bottoms further inland, gradually falling away to lakes, ponds, and marshes near the foot of the bluffs. Some exceptions to this rule are found at the deltas of the larger tributaries.
>
> In the upper river as far south as Beardstown, the river banks lie generally from 7 to 12 feet above low water, averaging about 10 feet. The lakes, many of them quite large, are connected with the river at low or medium stages of water and lie at approximately the same elevation as the river, rising and falling with it. The low-water connection is always at the foot of the lake. At moderate stages of flood they are connected with the river at their upper ends also, the lakes receiving and carrying a portion of the flood flow in its passage down the valley, and also acting as storage reservoirs, tending to reduce the maximum flow rate of the flood. In the lower river, below Beardstown, the immediate banks of the stream are higher, the filling of the bottom lands has progressed further, and the lakes are smaller, many of them lying 10 feet or more above low water in the main stream. They are thus only invaded by river stages considerably above normal.
>
> The course of the river is unusually direct, the filling of the flood plain having been insufficient to induce the tortuous courses of the Mississippi and like streams. Throughout the greater part of its length, particularly in the lower 60 miles,

---

[3] Leverett: The Illinois Glacial Lobe, Monograph 38, U. S. Geological Survey, 1899.

[4] Report to former Rivers and Lakes Commission on the Illinois River and Its Bottom Lands, by Alvord and Burdick, consulting engineers. State of Illinois, 1919.

the stream follows the base of the western hills, with occasional diversions toward the center of the valley where the stream has been pushed outward by the deposit at the mouth of an important tributary.

Throughout its course the low-water banks of the stream are thickly overgrown with trees and brush, and in the lower reaches of the river particularly, the bottoms are veritable jungles of trees, shrubs, and climbing vines. In its natural state all ground within a few feet of the low-water line in river and lakes was thus thickly overgrown, the only open places being the lakes and ponds and their low-lying borders submerged for a large part of the year, and during the low-water season covered with swamp grass and rushes.

Many of these fertile bottom lands are now being reclaimed by the construction of dikes and levees, which has resulted in greatly contracting the high-water area of flow with the consequent increase of flood-height elevation of the stream.

The drainage from tributaries of the Illinois is added to the main stream at rather irregular intervals. There are nine principal tributary streams with watersheds of approximately 1,000 square miles or over, and on all of which the daily discharge was determined during the course of these field studies. These branches, together with their drainage areas and stations of confluence with the main stream, are given in Table No. 2. The watersheds of the remaining tributaries are small, the largest being about 500 square miles in extent.

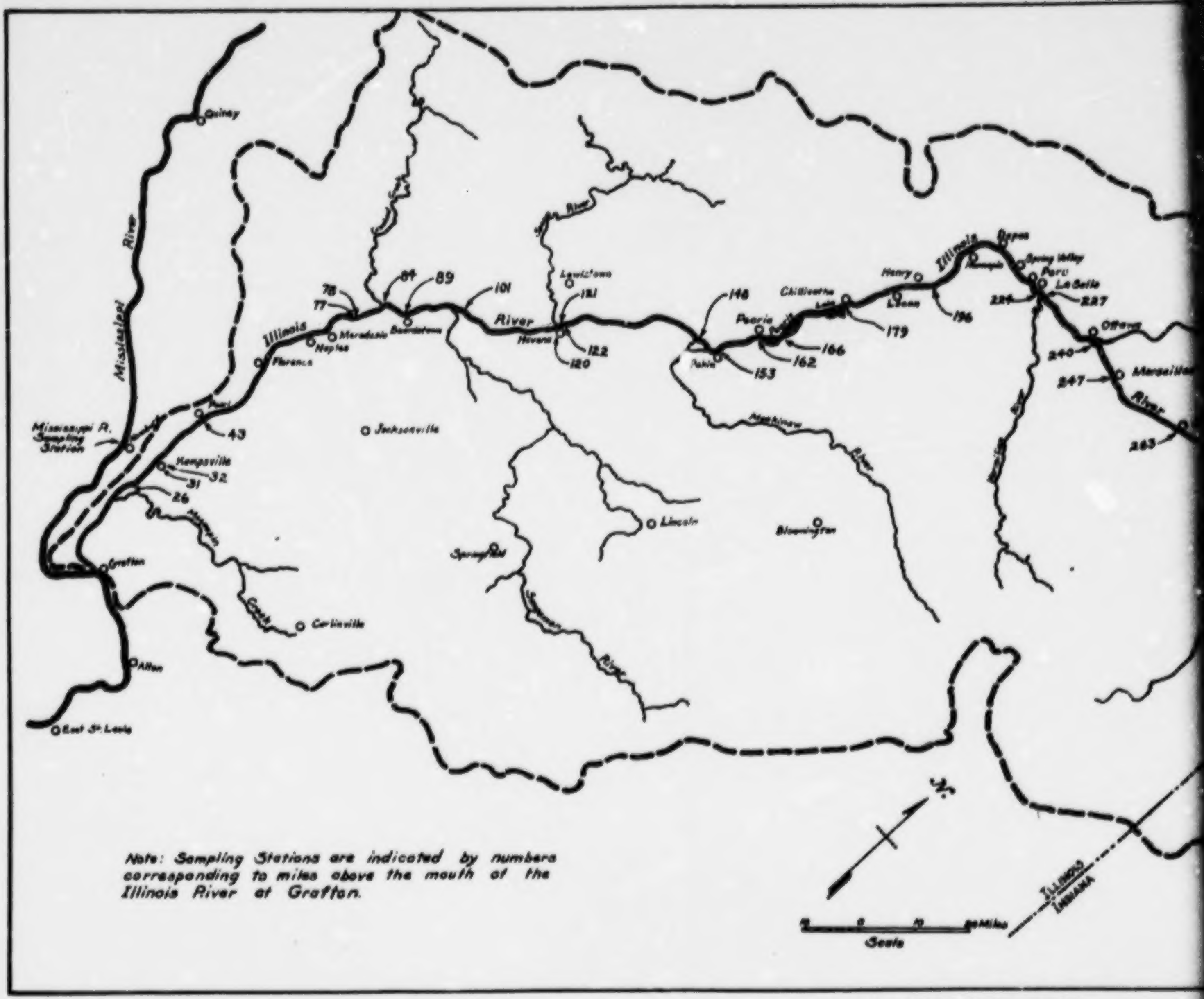
TABLE No. 2.—*Principal tributaries of the Illinois River*

Name	Drainage area	Area of total Illinois watershed	Station of confluence, above Grafton	Enters from east or west	Approximate place of confluence
	Sq. miles	*Per cent*	*Miles*		
Chicago Drainage Canal above Lockport.	217	0.8	[1] 291.0	....	
Des Plaines above junction with sanitary canal.	886	3.1	289.0	....	At Joliet.
Des Plaines	946	3.3	273.0	West	Below Joliet.
Kankakee	5,297	18.7	273.0	East	Do.
Fox	2,580	9.1	239.7	West	Ottawa.
Vermilion	1,261	4.4	226.5	East	La Salle.
Mackinaw	1,174	4.1	147.7	...do	Below Pekin.
Spoon	1,812	6.4	120.6	West	Havana.
Sangamon	5,332	18.8	88.0	East	Above Beardstown.
Crooked Creek	1,349	4.8	83.8	West	Below Beardstown.
Macoupin Creek	944	3.3	23.0	East	Above Hardin.

[1] Joins Des Plaines at Joliet.

THE PRESENT RIVER CHANNEL

The course of the present river channel is shown on the accompanying map of the Illinois River watershed (fig. 1), while the profile of the entire waterway from Lake Michigan to the junction with the Mississippi at Grafton, given in Figure 2, shows the relative elevations and slopes of the water level in various parts of the stream. The slope of the upper section, from Joliet to La Salle, is more marked, having an average fall of 1.5 feet per mile. Below La Salle


Mississippi River
Quincy
Mississippi R. Sampling Station
Illinois River
Florence
Naples
Meredosia
Beardstown
Jacksonville
Kampsville
Grafton
Alton
East St. Louis
Carlinville
Springfield
Lincoln
Bloomington
Lewistown
Havana
Peoria
Pekin
Chillicothe
Henry
Lacon
Depue
Spring Valley
Peru
La Salle
Ottawa
Marseilles
Mackinaw River
River
Creek
26
31
32
43
77
78
84
89
101
120
121
122
148
153
162
166
179
196
224
227
240
247
263
N
Scale
0
10
20 Miles
ILLINOIS
INDIANA

Note: Sampling Stations are indicated by numbers corresponding to miles above the mouth of the Illinois River at Grafton.

FIG. 1.—Map of the Illinois River watershed

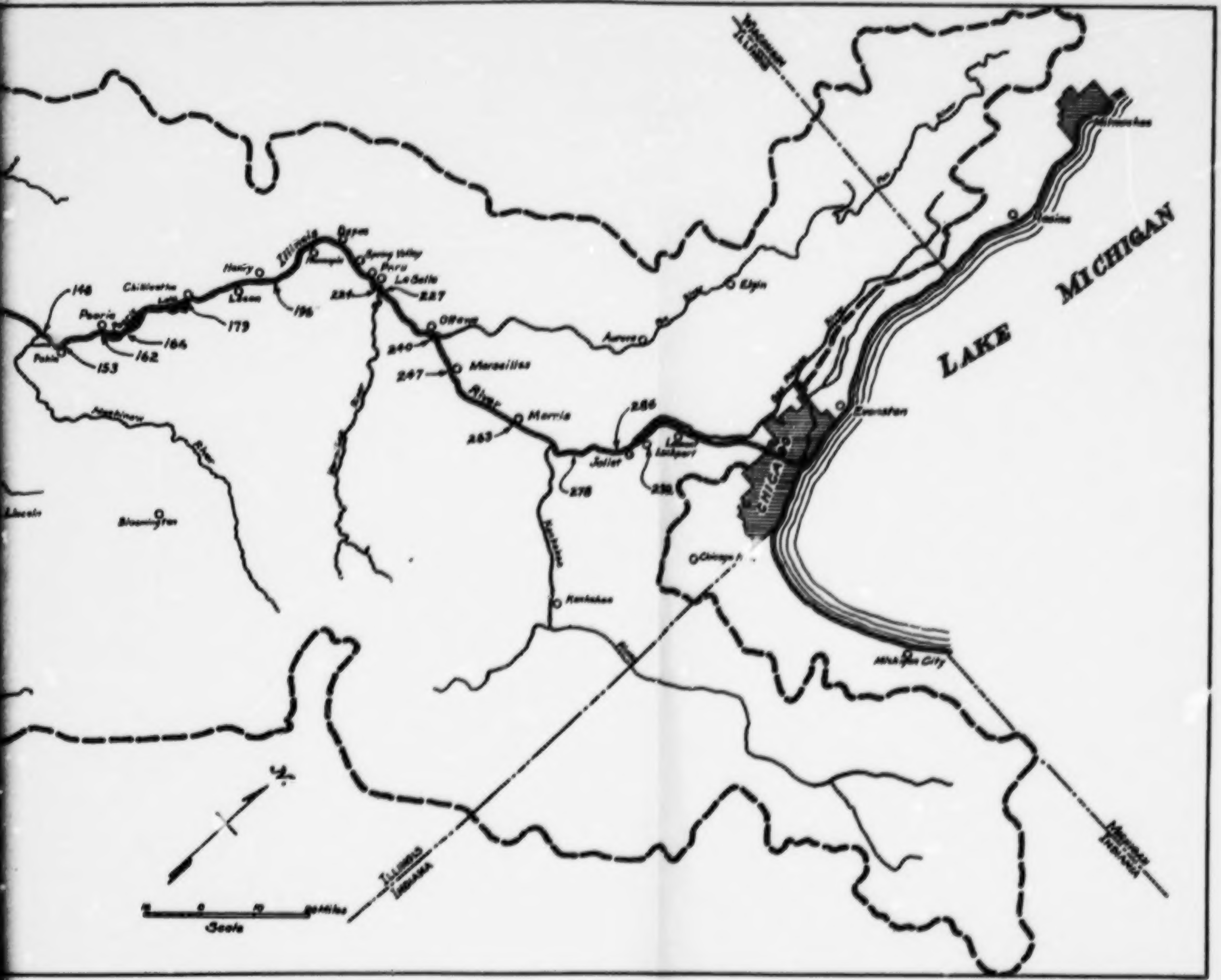

WISCONSIN
ILLINOIS
Milwaukee
Racine
LAKE MICHIGAN
Illinois
Depue
Spring Valley
Hennepin
Peru
La Salle
Henry
Lacon
Chillicothe
Peoria
Pekin
148
153
162
164
179
196
224
227
Ottawa
240
Marseilles
247
River
Morris
263
286
Joliet
Lockport
278
Aurora
Elgin
Evanston
CHICA
Chicago H
Kankakee
Kankakee
Michigan City
Mackinaw
River
Lincoln
Bloomington
ILLINOIS
INDIANA
MICHIGAN
INDIANA
10
0
10
20 Miles
Scale

FIG. 1.—Map of the Illinois River watershed

44002—27. (Face p. 6.)

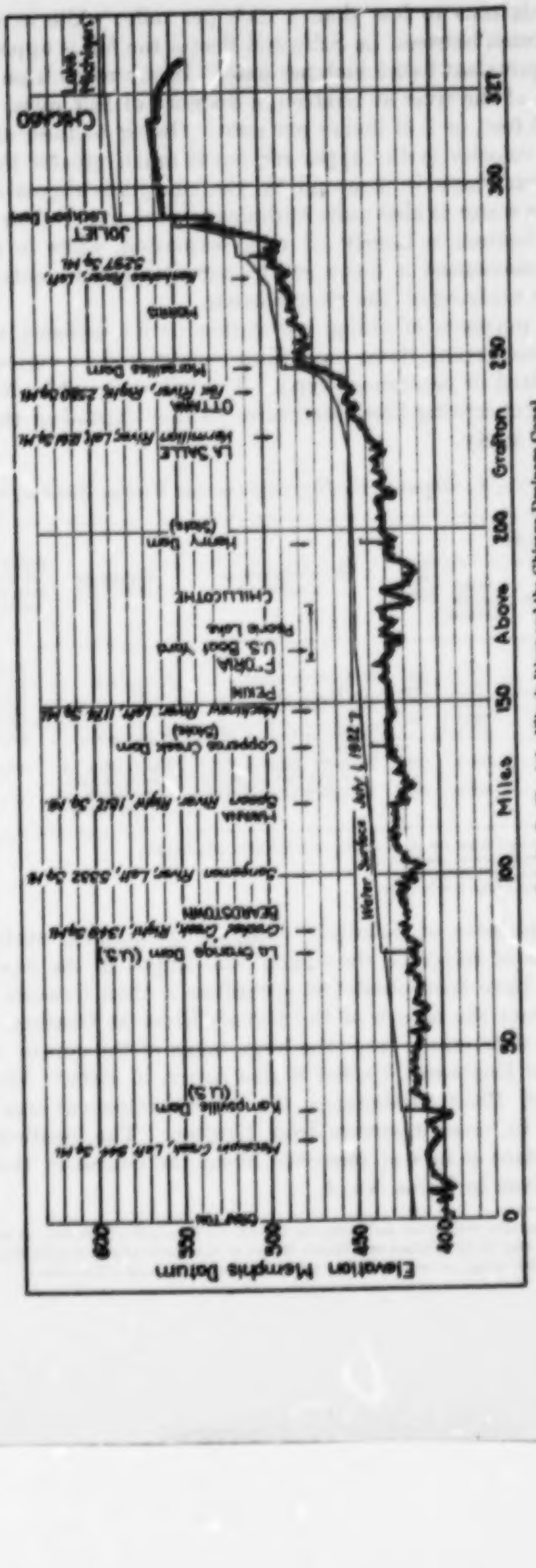


FIG. 2.—Profile of the Illinois River and the Chicago Drainage Canal

the slope flattens to less than 1 inch per mile, while in the entire 60-mile stretch between La Salle and Peoria the fall is approximately 2.5 feet, equivalent to 0.5 inch per mile. In the reach from Peoria to the mouth of the river at Grafton, a distance of 165 miles, the fall is about 19.5 feet, or 1.43 inches per mile. Owing to these changes of slope, the velocity in the upper reaches is much greater than in the lower section where, in some places, the current is almost imperceptible. The water is also quite turbulent in the upper channel where the river bottom is largely of rock formation, while in the lower river the movement is quite gentle, permitting sedimentation with consequent sludging of the river bottom.

For the purposes of aiding navigation or for utilizing the water power of the stream, dams have been constructed at various points, all of the fixed or permanent type. The following table, No. 3, presents data concerning these structures as they existed at the time of the present study.

TABLE No. 3.—*Dams in the Illinois River and Chicago Sanitary Canal*

Location of dam		Year completed	By whom built or maintained	Purpose for which built	Elevation of crest Memphis datum	Length of crest between abutments
General location	Miles above Grafton					
					Feet	*Feet*
Kampsville	31.5	1893	U. S. Government	Navigation	[1] 421.9	1,200
La Grange	77.6	1889	do	do	422.65	819
Copperas Creek	136.8	1877	State of Illinois	do	[2] 429.0	640
Henry	196.1	1871	do	do	[2] 443.3	540
Marseilles	247.0		Marseilles Land & Water Power Co.	Water power [3]	485.65	920
Joliet Dam No. 1	288.4	1920	Economy Light & Power Co. and State of Illinois.	Navigation & Water Power.	544.5	274
Lockport	291.0	1907	Chicago Sanitary District.	Navigation & Water Power[4].		

[1] Crest level lowered from elevation 423.9 to 421.9 during 1904 to 1906.
[2] Several changes between 1904 and 1906.
[3] Power available, 7,874 horsepower.
[4] Power available, 36,000 horsepower.

For the purpose of definitely designating sampling stations and other points of reference throughout the length of the channel, all such places have been numbered according to their location in miles upstream from the mouth of the Illinois River at Grafton, the distance being determined from the large maps of the survey made by the Corps of Engineers, United States Army, in 1904.[5] Thus, sampling station 120.9 (designated 121 for convenience) was located 120.9 miles by river upstream from Grafton. The locations of the more important points of reference along the course of the Illinois River are given in Table No. 4.

---

[5] Report upon survey, with plans and estimates of cost, for a navigable waterway 14 feet deep from Lockport, Ill., by way of Des Plaines and Illinois Rivers to the mouth of said Illinois River. House of Representatives, 58th Cong., 1st sess., Doc. No. 263. Government Printing Office, 1905.

TABLE No. 4.—*Location of cities, towns, bridges, gauges, sampling stations, etc., on the Illinois River*

[Populations of incorporated places from U. S. Census of 1920]

Name	Miles from Grafton	Side of channel	Remarks
Grafton, Ill	0.0	Left	United States gauge at quarry.
Otter Creek	14.8	...do	Drainage area, 56 square miles.
Guilford, Ill	17.2	Right	Unincorporated.
Hardin, Ill	21.2	...do	Population, 694.
Macoupin Creek (sampled)	23.0	Left	Drainage area, 944 square miles.
Sampling station	25.7		
Do	30.9		
Kampsville Lock	31.5	Right	Public Health Service branch laboratory and U. S. Engineers' gauges.
Kampsville, Ill	32.0	...do	Population, 498.
Apple Creek	36.3	Left	Drainage area, 418 square miles.
Sampling station	42.9		
Chicago & Alton R. R. bridge	43.2		U. S. Engineers' gauge on this bridge at Pearl.
Bedford, Ill	48.6	Left	Unincorporated.
Montezuma, Ill	50.2	Right	Do.
Big Sandy Creek	51.1	Left	Drainage area, 211 square miles.
Florence, Ill	55.6	Right	Unincorporated.
Wabash R. R. bridge	61.6		
Mauvais Terre Creek	63.1	Left	Drainage area, 230 square miles.
Naples	65.6	...do	Population, 294.
McGees Creek	66.6	Right	Drainage area, 424 square miles.
Wabash R. R. bridge	71.1		At Meredosia, Ill.
Meredosia, Ill	71.3	Left	Population, 810.
Sampling station	76.7		
La Grange lock	77.6	Right	U. S. Engineers' gauges, upper and lower levels.
Sampling station	78.0		
Indian Creek	78.8	Left	Drainage area, 256 square miles.
Crooked Creek (sampled)	83.8	Right	Drainage area, 1,349 square miles.
Crane Creek	83.9	...do	Drainage area, 41 square miles.
Sampling station	84.9		
Wagon Bridge	88.6		At Beardstown, discharge rating station.
Sampling station	88.6		At wagon bridge.
Beardstown, Ill	88.7	Left	Population, 7,111. Branch laboratory, U. S. Public Health Service.
Chicago, Burlington & Quincy R. R. bridge.	88.8		At Beardstown, U. S. Engineers' gauge.
Sampling station	89.3		Discontinued June 3, 1922.
Frederick, Ill	91.7	Right	Unincorporated.
Sugar Creek	94.3	...do	Drainage area, 180 square miles.
Browning, Ill	97.3	...do	Population, 486.
Sangamon River (sampled)	99.0	Left	Drainage area, 5,322 square miles.
Sampling station	100.8		
Bath, Ill	110.0	Left	Population, 408. Sanitary District gauge.
Otter Creek	111.6	Right	Drainage area, 110 square miles.
Wagon bridge	119.9		At Havana, Ill. U. S. Engineers' gauge.
Havana, Ill	120.1	Left	Population, 3,614.
Spoon River (sampled)	120.6	Right	Drainage area, 1,812 square miles.
Sampling station	120.9		
Quiver River	122.2	Right	Drainage area, 254 square miles.
Sampling station	122.5		
Liverpool, Ill	128.0	Right	Unincorporated. Sanitary District gauge.
Copperas Creek lock	136.8	...do	U. S. Engineers' gauges.
Copperas Creek	138.7	...do	Drainage area, 141 square miles.
Kingston Mines	145.5	...do	Population, 408.
Mackinaw River (sampled)	147.7	Left	Drainage area, 1,174 square miles.
Sampling station	147.9		
Chicago & North Western R. R. bridge.	151.2		
Outlet of Dead Lake	151.2	Left	
Sewer outlet, Corn Products Refining Co., of Pekin.	151.7	...do	Distillery wastes discharge just below this outlet.
Pekin, Ill	152.9	...do	Population, 12,086.
Wagon bridge	152.9		At Pekin, U. S. Engineers' gauge.
Peoria & Pekin Terminal bridge	153.0		At Pekin.
Sampling station	153.5		
Wesley City	159.2	Left	Unincorporated. Sanitary District gauge.
Kickapoo Creek	159.6	Right	Drainage area, 315 square miles.
Peoria & Pekin Union Ry. bridge	160.7		At Peoria, Ill.
Toledo, Peoria & Western Ry. bridge	162.2		Do.
Foot of Peoria Lake	162.3		
Lower wagon bridge	162.3		At Peoria. U. S. Weather Bureau gauge.
Sampling station	162.3		At lower wagon bridge.

TABLE No. 4.—*Location of cities, towns, bridges, gauges, sampling stations, etc., on the Illinois River*—Continued

Name	Miles from Grafton	Side of channel	Remarks
Peoria, Ill. (boat landing)	162.7	Right	Population, 76,121. Main laboratory, U. S. Public Health Service.
United States boat yard	165.0	do	At Peoria. U. S. Engineers' gauge.
Averyville	166.0	do	Population, 3,815.
Upper wagon bridge	166.1		At Peoria (Narrows).
Sampling station	166.1		At upper wagon bridge.
Mossville, Ill	172.0	Right	Unincorporated.
Spring Bay, Ill	173.8	Left	Population, 89.
Rome, Ill	177.8	Right	Population, 216.
Head of Peoria Lake	178.5		
Sampling station	179.0		
Chillicothe, Ill	180.5	Right	Population, 1,986.
Gauge at Chillicothe, Ill	180.5	do	Maintained by Chicago Sanitary District.
Santa Fe Ry. bridge	181.9		
Lacon	189.1	Left	Population, 1,464.
Wagon bridge	189.1		At Lacon.
Henry	196.0	Right	Population, 1,637.
Wagon bridge	196.0		At Henry, sampling station.
Henry lock	196.1	Right	U. S. Engineers' gauge.
Hennepin, Ill	207.4	Left	Population, 377.
Bureau Creek	209.0	Right	Drainage area, 490 square miles.
Illinois and Mississippi (Hennepin) Canal.	210.2	do	
Depue C. I. & S. R. R. bridge	213.9		Sanitary District gauge.
Marquette, Ill	214.9	Right	Unincorporated.
Spring Valley	218.4	do	Population, 6,493.
Wagon bridge	218.4		At Spring Valley.
Peru	222.4	Right	Population, 8,869.
Wagon bridge	222.4		U. S. Weather Bureau gauge.
Illinois-Michigan Canal	223.2	Right	
La Salle		do	Population, 13,050.
Wagon bridge	224.5		At La Salle.
Sampling station (temporary)	224.5		Wagon bridge.
Chicago, Burlington & Quincy R. R. bridge.	225.4		At La Salle.
Illinois Central R. R. bridge	225.5		Do.
Little Vermilion River	225.6	Right	Drainage area, 121 square miles.
Vermilion River (sampled)	226.5	Left	Drainage area, 1,261 square miles
Sampling station	226.8		
Wagon bridge	229.7		At Utica.
Utica	229.7	Right	Unincorporated.
Starved Rock	230.9	Left	State park.
Buffalo Rock	235.0	Right	Do.
Gauge at La Salle County poor farm	236.0	do	Maintained by Sanitary District.
Chicago, Burlington & Quincy R. R. bridge.	239.4		At Ottawa, Ill. Sanitary district gauge
Ottawa, Ill	239.5	Right	Population, 10,816.
South Ottawa, Ill	239.5	Left	Unincorporated.
Wagon bridge	239.6		At Ottawa.
Fox River (sampled)	239.7	Right	Drainage area, 2,580 square miles.
Sampling station	239.9		
Bells Island	244.5		
Wagon bridge	246.8		At Marseilles.
Marseilles, Ill	247.0	Right	Population, 3,391.
Marseilles Dam	247.0		
Sampling station	247.3		
Wagon bridge at Seneca	252.7		Sanitary District gauge.
Seneca	252.9	Right	Unincorporated.
Cleveland, Cincinnati, Chicago & St. Louis R. R. bridge.	254.0		
Wagon bridge at Morris	263.2		U. S. Weather Bureau and Sanitary District gauges.
Morris	263.2	Right	Population, 4,505.
Sampling station	263.2		At Morris wagon bridge.
Mazon Creek	263.4	Left	Drainage area, 507 square miles.
Au Sable Creek	268.2	Right	Drainage area, 200 square miles.
Elgin, Joliet & Eastern R. R. bridge	270.7		Sanitary District gauge.
Kankakee River (sampled)	273.6	Left	Drainage area, 5,297 square miles.
Dupage River	277.3	Right	Drainage area, 341 square miles.
Smith's wagon bridge	277.6		Sanitary District gauge.
Sampling station	277.6		At Smith's wagon bridge.
Brandon road bridge	285.8		
Sampling station	285.8		Brandon road bridge.
Joliet	288.0	Both	Population, 38,442.
Sampling station	287.3		McDonough Street Bridge.
Chicago, Rock Island & Pacific R. R. bridge.	287.6		At Joliet.
Jefferson Street Bridge, Joliet	287.9		
Sampling station	287.9		Jefferson Street Bridge.
Cass Street Bridge, Joliet	288.1		

TABLE No. 4.—*Location of cities, towns, bridges, gauges, sampling stations, etc., on the Illinois River*—Continued

Name	Miles from Grafton	Side of channel	Remarks
Sampling station	288.1		Cass Street Bridge.
Jackson Street Bridge, Joliet	288.4		Jackson Street Bridge.
Sampling station	288.4		
Automatic recording gauge	288.4		At Jackson Street Bridge. Maintained by U. S. Geological Survey.
Dam of Economy Light & Power Co.	[illegible].4		
Head of Illinois & Michigan Canal	288.4	Right	
Sampling station	288.7		Ruby Street bridge.
Junction of Des Plaines River and main drainage canal.	288.8		
Dam and power plant and drainage canal lock at Lockport.	291.0		Drop through this plant about 35 feet. Population of Lockport, 2,684.
Sixteenth Street Bridge, Lockport	292.0		
Sampling station	292.0		Sixteenth Street bridge at Lockport. Samples were collected from the drainage canal and from the Des Plaines River. The Des Plaines River sampling station was later moved to Lemont.
Drainage canal control works	293.1		At Lockport.
Lake Michigan, Chicago	327.0		Mouth of Chicago River.
Chicago			Population, 2,701,705.

CHAPTER II

POPULATION OF THE ILLINOIS RIVER WATERSHED AND SOURCES OF POLLUTION OF THE RIVER

The wastes which contribute to the pollution of streams originate from two principal sources: (*a*) The artificial drainage of urban communities, consisting of the domestic sewage contributed by the population, combined with varying quantities of street wash and the discharge from industrial plants using considerable volumes of water for transporting waste products, the whole mixture constituting what is generally known as "combined sewage," and (*b*) the surface run-off from all portions of the watershed, carrying more or less of eroded soil, combined with indeterminate amounts of domestic wastes of the rural population. In terms of polluting effect, the wastes contributed as domestic sewage from different communities are generally proportionate to the respective numbers of persons contributing to the sewers. Therefore the contributions from different communities on a watershed may be compared or summed up in terms of the sewered population. It is also possible, to a limited extent, to summarize the waste from certain industrial processes in terms of the sewered population, which would contribute equivalent pollution in the form of domestic sewage, so that at least a rough quantitative estimate may be made of the combined domestic and industrial waste from a series of urban communities. The wastes contributed as surface drainage from unsewered areas vary so much according to topography, character of the soil, state of cultivation, distribution of rainfall, and other more or less indeterminate factors that they can not be estimated in any significant quantitative terms. Therefore the summaries and estimates which follow refer chiefly to sewered populations and industrial waste.

POPULATION

Population data, as given in United States census reports, are assembled by political subdivisions of the State, the primary civil division being the county, which is further subdivided into townships or districts, within which are separate "incorporated places," that is, cities or villages. Since the boundaries of these civil divisions seldom correspond to the boundaries of watersheds, which are defined by natural contours, it is necessary, in computing the population of a watershed area, to rearrange the data given in the census reports for civil divisions. This rearrangement involves the following steps:

1. Demarcation of the watershed boundaries on maps which show also the boundaries of civil divisions for which population figures are

given in the United States census reports. The base maps used for this purpose are United States post route maps, showing the boundaries of counties, the location of all incorporated places, and with fair accuracy the course of all streams. Watershed boundaries have been marked off on these maps by interpolation between the streams shown, or by transfer from United States Geological Survey topographic maps where these were available.

2. Simple summation of the populations of civil divisions lying wholly within the watershed area. This applies to (*a*) counties wholly within the watershed and (*b*) incorporated villages lying within the watershed in counties which are intersected by the watershed boundary, the proper locations of such cities and villages being shown on the reference maps.

3. Apportionment to the watershed of a proper part of the population of each county which lies partly within and partly without the watershed. The population of all the incorporated places in such a county having been subtracted from the total for the county and properly allocated, it has been assumed that the residual population, consisting of the residents in unincorporated areas, is uniformly distributed over the entire area of the county, so that any given fraction of the area will contain a corresponding fraction of this population. On this assumption planimeter measurements have been made on the reference maps of the entire area of each intersected county and of that area lying within the watershed, and the population has been allocated accordingly.

The population of each watershed, computed in this way, has then been classified into "urban" and "rural," following in this classification the practice of the United States Census Bureau, which defines as "urban" the population residing in incorporated communities which at the time of the census had 2,500 inhabitants or more, the residual population being classed as "rural."

In order to provide a basis for estimating the populations as of the time when this study was in progress, computations of population for each watershed were made from the census records of 1910 as well as from those of 1920. The study of the Illinois River was begun in April, 1921, and continued until September, 1922; hence January 1, 1922, represents approximately the mid-point of the study, and population estimates were extended to this date, using the method of the United States Census Bureau, which assumes for the post-census period the same arithmetical rate of increase as obtained in the interval between the last two census enumerations.

It is obvious that estimates of watershed populations made in this way can not be precise, and the apparently precise figures which are given in the tables herewith are used in preference to round numbers merely as a matter of convenience to maintain consistency in the totals. Where reference is made to these figures in the text, they are usually stated in round numbers.

Because of the dense population of Cook County, Ill., and also because of the changes in natural drainage effected by intercepting sewers, sewage-pumping stations, and the main drainage canal, a somewhat different method was followed in computations of population in this area. The divides between the Des Plaines, Fox, Dupage, Chicago, and Calumet Rivers were carefully outlined on a large-scale map of the county, and the percentages of the total area draining to the different tributaries were determined to be:

	Per cent
To main drainage canal	36.2
To Des Plaines River	27.1
To Fox River	7.2
To Dupage River	.5
Total per cent of county draining to Illinois River	71.0

The population of incorporated places within these areas, other than that of Chicago, was properly allocated and the remaining rural population proportioned according to the areas within the watershed boundaries. The population of the city of Chicago sewered to the main drainage canal was estimated by deducting from the total population of the city the part south of Eighty-seventh Street that is otherwise provided for, using the city sewer maps and ward populations in the computation. The population of Chicago tributary to the main drainage canal as thus computed for 1910 was 2,097,233 and for 1920 was 2,567,319.

For the purpose of this study the population attributed to the Illinois River direct comprises all the population tributary to the main waterway from Lake Michigan to the mouth of the Illinois River at Grafton, including that served by the main drainage canal and that attributed to the Des Plaines includes only the population tributary to this river above the junction with the main drainage canal at Lockport.

By methods similar to those described above the population above each point on the river at which samples were collected for bacterial and chemical examination, as well as above the mouth of each of the principal tributaries, was computed as of January 1, 1922. This distribution of population on the watershed is given in Table No. 6.

TABLE No. 5.—*Population of the Illinois Drainage Basin by tributary watersheds*

Watershed	Area in square miles	Population in 1910			Population in 1920			Population, Jan. 1, 1923		
		Total	Urban	Rural	Total	Urban	Rural	Total	Urban	Rural
Illinois direct	7,455	2,661,149	2,369,315	291,834	3,234,518	2,961,144	273,374	3,340,779	3,071,002	269,777
Du Page	341	29,433	9,743	19,690	34,995	16,955	18,040	36,195	18,496	17,699
Des Plaines	799	75,482	27,171	48,311	109,753	66,667	43,086	116,812	74,104	42,708
Kankakee	5,297	213,085	33,481	179,604	272,255	99,267	172,988	229,049	53,322	175,728
Fox	2,580	191,964	81,630	110,334	207,580	95,712	112,867	210,773	96,200	114,573
Vermilion	1,261	65,057	26,042	39,015	64,970	28,110	36,860	64,973	28,549	36,424
Mackinaw	1,174	40,332		40,332	38,773		38,773	38,449		38,449
Spoon	1,812	96,137	22,379	73,758	100,221	37,995	62,226	101,646	41,213	60,433
Sangamon	5,312	333,415	140,700	192,715	361,170	167,795	193,375	362,394	173,959	188,435
Crooked Creek	1,349	53,496	5,774	47,722	51,259	6,714	44,545	50,811	6,925	43,886
Macoupin Creek	964	41,640	7,729	33,911	41,340	9,051	32,289	41,300	9,323	31,977
Total	28,344	3,801,189	2,723,964	1,077,225	4,456,816	3,425,831	1,030,985	4,588,150	3,570,617	1,017,533

TABLE No. 6.—*Drainage areas and total population above various points on the Illinois River*

Miles from mouth	Above and including tributary	Drainage area in square miles	Population, Jan. 1, 1922		
			Total	Urban	Rural
[1] 292.0		217	2,864,596	2,839,847	24,749
288.8	Des Plaines	1,016	2,981,409	2,913,951	67,458
[1] 285.8		1,122	3,031,467	2,955,880	75,587
[1] 277.6		1,194	3,037,229	2,955,880	81,349
277.3	Du Page	1,535	3,073,424	2,974,376	99,048
273.0	Kankakee	6,862	3,298,328	3,025,614	272,714
[1] 263.2		7,599	3,326,911	3,029,242	297,669
[1] 247.3		7,842	3,333,398	3,029,242	304,156
[1] 239.9		7,865	3,337,589	3,032,664	304,925
239.7	Fox	10,456	3,548,362	3,129,854	418,508
[1] 226.8		10,589	3,565,239	3,139,934	425,305
226.5	Vermilion	11,900	3,630,201	3,168,474	461,727
[1] 196.0		12,611	3,704,262	3,208,398	495,864
[1] 179.0		13,356	3,724,171	3,211,416	512,755
[1] 166.1		13,380	3,733,408	3,211,416	521,992
[1] 153.5		14,015	3,827,648	3,283,478	544,170
[1] 147.9		14,110	3,854,376	3,306,015	548,361
147.7	Mackinaw	15,284	3,892,825	3,306,015	586,810
[1] 120.9		15,838	3,914,045	3,306,015	608,030
120.6	Spoon	17,650	4,015,111	3,347,228	667,883
[1] 100.8		17,957	4,027,038	3,350,860	676,178
99.0	Sangamon	23,289	4,390,402	3,524,769	865,633
[1] 88.6		23,516	4,396,437	3,524,769	871,668
83.8	Crooked Creek	25,137	4,447,238	3,531,677	915,561
[1] 76.7		25,456	4,466,956	3,538,995	927,961
[1] 42.9		26,628	4,521,088	3,554,788	966,300
[1] 30.9		27,154	4,540,240	3,561,294	978,946
[1] 25.7		27,186	4,541,583	3,561,294	980,289
23.0	Macoupin Creek	28,147	4,582,883	3,570,617	1,012,266
0.0	Mouth of Illinois River	28,344	4,588,150	3,570,617	1,017,533

[1] Sampling station.

According to this table the total population on the watershed of the Illinois River is 4,588,000, of which 3,570,600, or about 78 per cent, is classed as urban. The population of the watershed is, to a remarkable extent, concentrated in the small area of 217 square miles above station 292 at Lockport on the Chicago Drainage Canal. Thus, above this point the combined urban and rural population is estimated at 2,864,600, which is about 52 per cent of the total for the entire watershed, and the urban population at 2,840,000, which is nearly 80 per cent of the entire urban population.

SEWAGE POLLUTION

Since it is the sewered population which is of principal importance in relation to stream pollution, and since no assembled data on this population were available, sanitary surveys of all incorporated places were made, either by the Public Health Service or by the State boards of health, to ascertain, among other things, the numbers of persons contributing sewage to the watercourses. The data thus collected are presented in Table No. 7, in which the sewered population tributary to the river system (i. e., the main stream and its tributaries) above each sampling station, is shown distributed according to distance, by river, above the sampling station, in 50-mile zones. Table No. 8 shows the sewered population on each of the principal tributary watersheds, similarly distributed into 50-mile zones according to distance from the mouth of the tributary.

Table No. 7.—*Sewered population by 50-mile zones above each sampling point on the Illinois River*

Sampling point	50-mile zone								
	Under 50	50-100	100-150	150-200	200-250	250-300	300-350	350-400	Total
292	2,834,351	0							2,834,351
286	2,926,118	4,615							2,930,733
278	2,882,618	63,225	0						[illegible]
263	63,884	2,934,750	15,210	2,764					[illegible]
247	81,814	2,958,985	5,946	16,484					[illegible]
240	31,704	2,941,686	18,699	16,424					[illegible]
227	16,878	2,982,967	96,187	28,645	0				3,108,377
196	48,301	82,498	2,976,786	22,475	16,424				3,146,485
179	88,031	30,066	2,982,667	65,157	28,645	0			3,196,878
166	3,023	51,934	126,331	2,939,538	25,585	2,704			3,150,076
153	76,546	50,907	80,762	2,986,064	17,158	15,464			3,226,901
146	80,307	50,007	80,762	2,982,641	16,621	16,424	0		3,226,762
123	76,084	13,761	50,904	2,980,880	72,518	25,881	2,704		3,222,446
101	8,696	86,125	58,756	80,762	2,980,434	19,787	13,404		3,247,813
89	1,476	156,303	97,209	90,197	2,980,880	23,388	27,088		3,364,565
77	37,547	174,611	44,931	32,524	2,988,556	65,157	25,645		3,376,901
43	16,010	7,697	162,136	91,953	90,662	2,973,406	15,677	27,090	3,387,711
31	11,470	8,816	113,976	132,296	33,765	3,007,055	52,688	27,645	3,387,711
26	13,540	9,229	117,725	12[illegible],894	33,765	2,998,556	65,187	28,045	3,390,531

Table No. 8.—*Sewered population on tributary watersheds of the Illinois River by 50-mile zones from their mouths*

Tributary	Drainage area in square miles	Station of mouth on Illinois River	50-mile zone above mouth				Total sewered population
			Under 50	50-100	100-150	150-200	
Des Plaines	[1] 686	288.8	72,474	2,545	0	0	75,019
Dupage	341	277.3	19,764	0	0	0	19,764
Kankakee	5,297	273.0	24,311	7,050	17,970		49,331
Fox	2,580	239.7	40,635	29,524	4,629	10,675	85,463
Vermilion	1,261	226.5	12,289	889	0	0	13,178
Mackinaw	1,174	147.7	693	1,989	0		2,682
Spoon	1,812	120.6	8,618	5,848	4,986	0	19,452
Sangamon	5,332	99.0	949	69,927	43,878	0	114,754
Crooked Creek	1,349	83.8	231	4,105	0	0	4,336
Macoupin Creek	944	23.0	5,428	0	0	0	5,428

[1] Area above junction with main drainage canal at Joliet.

The estimated total of the sewered population on the watershed is 3,390,500, of which 2,834,350, or about 83.6 per cent, are tributary to the Chicago Drainage Canal, above Lockport (station 292). The sewered population on the whole watershed is about 95 per cent of the entire urban population, from which it might be inferred that the sewerage of cities in this area is much more complete than on the watershed of the Ohio River, where the sewered population in 1915 amounted to only about 72 per cent of the entire urban population.[1] The high ratio of sewered to urban population on the Illinois watershed is due, however, to the nearly complete sewerage in the Sanitary District of Chicago, above Lockport, where the sewered population is about 99.8 per cent of the urban. On the remainder of the watershed the urban population is estimated at 730,770 and the sewered population at 556,180, which is about 76 per cent, a ratio not widely different from that given for the Ohio watershed.

---

[1] Public Health Bull. No. 143, Washington, 1924, p. 68.

As may be inferred from this concentration of sewered population in the Sanitary District of Chicago, the discharge of the main drainage canal at Lockport contributes an enormous sewage load to the river at this point. This discharge consists of a mixture of water diverted from Lake Michigan through the inlets previously described and the combined sewage—that is, domestic sanitary sewage, industrial wastes, and surface drainage—from the Chicago Sanitary District. The ratio of sewage to lake water, though varying from day to day and even from hour to hour, is roughly about 1 to 8. This effluent is by no means a fresh mixture of sewage and lake water, the dilution of the sewage having been effected at distances varying from roughly 20 to 50 miles above Lockport. The time represented by travel through the canal by these distances is not at all accurately determinable, but probably ranges between 18 and 60 hours, the former being an estimate of about the minimum time of flow to Lockport from the last point at which any considerable amount of sewage is discharged into the canal. Previous to such admixture with lake water much of the combined sewage has consumed varying periods of time in passage through the collecting system of sewers, pumping stations, interceptors, etc., comprising the drainage system of the district, so that altogether the effluent of the canal is generally in an active state of decomposition at Lockport.

SEWAGE TREATMENT

Practically none of the sewage reaching the Illinois River or its tributaries is treated before discharge, so that dilution and natural purification alone have been depended upon to effect such improvement as may occur. As a result, the upper Illinois is notoriously polluted by the overwhelming burden of sewage and wastes received from the main drainage canal and from the cities along its banks. This condition existed unchanged practically throughout the period of the present investigation. On August 1, 1922, the Sanitary District of Chicago placed in operation the Des Plaines River activated sludge-treatment plant, serving an estimated population of 40,000 located in towns draining to the Des Plaines River above Lockport. The limited number of observations made on the Des Plaines after that date were insufficient to exert any appreciable effect on the general trend of the results of this study.

Extensive plans for the treatment of a large percentage of the domestic sewage and industrial wastes of the Sanitary District are in course of preparation, and when such works are constructed and placed in operation will doubtless relieve to a considerable extent the present overburdened condition of the stream.

POLLUTION DUE TO INDUSTRIAL WASTES

To determine the extent of pollution of the Illinois River due to industrial wastes, a reasonably complete survey was made of the industrial establishments on the watershed of the types that discharge considerable amounts of liquid wastes into the watercourses. These data were secured, where possible, from existing records, from the State boards of health, and in the case of the city of Chicago, from the Sanitary District of Chicago, which has been engaged in an intensive study of the industrial wastes for a number of years. Except in the case of plants at which special studies had previously been made, it was rarely possible to secure exact information concerning the volume and composition of the wastes discharged. Fairly complete information was obtained, however, as to the nature of the processes used, the volume of water used for various purposes, the number of employees, the amounts of raw materials used, and the amounts of finished products turned out. From these data estimates of the corresponding waste constituents have been made where the information available has seemed to warrant the attempt. Such estimates were made as follows: The records of previous studies of the wastes from typical and important processes producing organic wastes were assembled from numerous sources. By combining such records pertaining to any particular process as seemed fairly comparable, computations were made of the average weights of various analytically determined constituents contained in the wastes produced in converting a given amount of raw material or in manufacturing a given amount of finished product. The factors thus obtained have then been applied to the data collected in this survey, which have usually been in terms of the amounts of raw materials used or finished product delivered by each plant. The factors used for this purpose are shown in Table No. 9, following. It is not claimed that estimates made in this way are at all exact, but there appears to be no other practicable method of summarizing organic industrial wastes in terms which are at all common to the various classes represented.

TABLE No. 9.—*Estimated average amounts of certain constituents contained in industrial wastes from various industries per unit of raw material or product*

[From Table No. 48, p. 79, Public Health Bulletin No. 143, with revision of certain conversion figures due to the inclusion of new available data]

Industry	Specific nature	Unit of raw material or product	Gallons waste per unit	Constituents in waste in kilograms per unit							
				Solids				Total nitrogen	Oxygen consumed	Biological oxygen demand	
				Total	Suspended	Dissolved	Volatile			5 days	20 days
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Brewing		1 barrel beer	132	1.932	0.200	1.732	1.443	0.080	0.755	1.079	1.419
Distilling		1 barrel whisky (10 bushels mashed grain).		28.980	11.886	17.094	25.90	.073	22.073		
Slaughtering and meat packing.	Combined waste	Per animal killed	360	6.060	1.053	5.007	2.735	.176	.067	1.311	1.735
	General packing house	do	601	6.620	1.324	5.296	3.310	.252	.252	2.113	2.778
	General slaughterhouse	do	359	6.237	1.262	5.047	3.135	.440	.080	2.062	4.089
	Pork packing	do	228	5.124	1.036	4.106	2.788	.236	.286	1.681	2.173
	Hog killing	do	143	1.940	.388	1.552	.971	.086	.109	.567	.637
	Cattle slaughtering	do	760	6.124	1.125	4.999	3.061	.330	.369	1.488	2.080
	Lard and sausage	do	44	1.740	.348	1.392	.870	.067		.362	.579
Rendering		Per employee	424	7.080	.028	7.088	1.941	.400	1.585	2.080	2.053
Glue		do	2,920	37.36	10.03	27.33	26.140	2.136	4.427	1.438	2.243
Grease and oil		do	185	3.117	.037	2.094	1.088	.016	.473	.180	.181
Soap		do	1,180	71.075	20.489	40.582	26.237	.037	20.347	1.089	2.446
Paper industries	Sulphite pulp	Ton of product	8,000	1,184.0		1,134.0	887.0	1.316	645.0		
	General paper mill	do	57,300	194.6	96.5	106.1	77.0	19.80	29.9		
	Leather board	do	11,300	59.45	30.5	29.0	60.5	2.15	44.0		
	Strawboard	do	25,000	862.0	215.0	367.0	641.0	5.715	132.0	112.0	262.0
	Straw and paper board	do	28,100	252.5	108.3	174.2	222.0	2.0	72.0	67.0	87.0
Textile industries	Wool scouring (grease wool)	100 pounds product	121	20.83	9.99	10.94	13.27	.340	1.256		
	Wool yarn and cloth scouring	do	2,330	7.371	2.186	5.085	4.558	.055	1.37		
	Wool yarn and cloth dyeing	do	600	3.923	.072	2.276	1.167	.162	.705		
	Wool yarn and cloth dyeing and scouring	do	6,000	51.720	4.387	47.413	8.891	.701	7.112		
	Wool and mixed goods, washing and dyeing.	do	2,000	17.322	1.267	15.985	2.062	.330	2.373		
	Cotton yarn and cloth bleaching	do	4,000	26.095	4.373	21.730	12.958	.320	5.460		
	Cotton yarn and cloth dyeing	do	1,100	8.260	.860	7.415	3.058	.062	1.979		
	Cotton yarn and cloth bleaching and dyeing.	do	4,300	52.16	10.60	41.56	10.65	1.111	6.160		
	Cotton-cloth bleaching, dyeing, and finishing.	do	8,800	14.59	2.40	12.16	2.80	1.224	.707		
	Silk washing and dyeing	do	34,000	81.65	36.30	45.35	45.00	1.062			

Tanning	Hide tannery	1 hide	270	3.12	1.86	3.36	2.80	.163	1.391	1.26	1.80
	Calfskin tannery	1 skin	75	1.71	.52	.39	.53	.045	.384	.35	.50
	Sheepskin tannery	1 dozen skins	45	1.48	.51	.57	.33	.027	.122		
	Harness leather	1 hide	333		2.48			.141	1.015	1.77	2.23
Corn products		1 bushel	230	.842	.153	.689		.0576	.341	.40	.04
Canning	Tomato canning	1 case	11.6		.111			.0127	.0390	.34	.37
Dairy products	General creamery	100 pounds butter	317	3.97	.868	3.10		.128	.999	2.81	3.47
Domestic sewage		1 person		.420	.109	.330	.183	.0114	.0513	.076	.10

Various observers have, from time to time, made careful studies of the volume and composition of the combined sewage from residential districts of known population, and where industrial wastes are absent or of small import; and from these data have calculated the average weights of various sewage constituents discharged daily per capita of population. The results of different observers vary considerably, but are in such general agreement that it is permissible to combine them into a rather general statement of the usual per capita contributions of sewage constituents in the same terms that are used in Table No. 9 to describe industrial wastes. Then, given the amount of any analytically determined constituent, such as "total nitrogen," which is discharged in a group of industrial wastes, it is possible to calculate the number of persons required to contribute an equal amount of this constituent in domestic sewage. This may be called the "population equivalent" of the industrial waste with respect to that particular constituent. Since the ratios of different constituents to each other are not the same in industrial wastes as in domestic sewage, the "population equivalent" of a given industrial waste with respect to "total nitrogen" will not be the same as the population equivalent for some other constituent, such as "oxygen consumed."

It should be stated, as regards these "population equivalents," that they are not to be interpreted too literally as true equivalents. In the first place the data available for calculation of conversion factors are, in many instances, woefully deficient. Also it is to be remembered that equal weights of, say, total nitrogen, contained, respectively, in an industrial waste and in sewage, do not necessarily represent equal polluting effects upon a stream, since the nitrogenous matters may differ greatly in state of combination or in physical state, and consequently in putrescibility or offensiveness. Statements in terms of "biological oxygen demand" would probably represent more nearly true equivalents, but accurate determinations of biological oxygen demand are, unfortunately, lacking for many important industrial wastes.

To illustrate the method followed in calculating population equivalents for industrial wastes, the calculations for the industrial wastes of Chicago will be presented rather fully:

The meat packing industry is the largest contributor of industrial waste pollution to the main drainage canal. During the period from June, 1921, until August, 1922, the number of animals slaughtered monthly is given in Table No. 10, from which the daily average total kill may be derived.

TABLE No. 10.—*Record of animals slaughtered at Chicago, June, 1921, to August 1922, inclusive*

Month	Working days	Animals slaughtered						Average kill per day
		Cattle	Calves	Hogs	Sheep	Horses	Total	
1921								a
June	26	152,006	72,304	364,394	209,373	0	1,098,226	41,588
July	26	114,179	34,129	497,758	236,411	382	882,859	32,653
August	27	147,960	46,982	423,466	348,237	169	960,782	35,584
September	26	155,196	50,188	380,270	317,680	148	911,424	35,056
October	26	164,518	44,909	542,224	282,819	427	1,034,894	39,804
November	26	158,260	40,773	580,626	290,761	728	1,026,156	39,466
December	27	120,301	45,110	437,168	214,208	187	806,974	29,888
1922								
January	26	155,869	56,861	593,907	237,060	0	1,033,729	39,874
February	24	135,976	53,881	614,282	242,467	550	1,047,151	43,631
March	27	148,965	84,086	498,189	197,072	588	928,810	32,326
April	26	130,343	71,745	400,607	169,122	650	772,547	29,713
May	27	190,368	76,191	554,744	240,403	315	1,061,906	39,330
June	26	180,230	73,833	626,727	263,636	299	1,144,717	44,026
July	26	167,666	58,666	464,857	247,297	482	932,968	35,881
August	27	177,073	80,056	457,702	233,850	125	918,906	34,034
Total	388	2,321,603	862,189	7,366,986	3,648,268	4,883	14,462,977	583,094
Daily average		5,948	2,245	18,794	9,317	12		36,867

From published studies of the stockyards wastes at Chicago,[2] the waste from a large number of plants of this industry averaged 601 gallons per animal killed, and was of the general composition given in column 1 of Table No. 11. Since the average volume of waste per animal killed is known, the figures in column 1 may be converted into terms of weights of constituents per animal handled daily as given in column 2 of the same table. The per capita contribution of similar constituents, in pounds daily contained in average domestic sewage, composed of household wastes and street wash, is given in column 3, which presents for each constituent a basis of comparison. The number of persons required to contribute, in domestic sewage, the same amount of each constituent as contributed by one animal handled in the stockyards is, therefore, the quotient of the figures in column 2 divided by corresponding values in column 3, as presented in column 4.

TABLE No. 11.—*Derivation of population equivalent of packingtown wastes*

	(1) Parts per million in general packing-house waste	(2) Pounds per animal	(3) Average per capita contributions in domestic sewage[a]	(4) Population equivalent per animal
Total solids	2,910	14.566	0.9679	15.06
Suspended solids	582	2.918	.2403	12.14
Dissolved solids	2,328	11.676	.7276	16.05
Volatile solids	1,455	7.287	.4012	18.16
Free ammonia	42	.210	.0167	12.57
Total nitrogen	111	.557	.0251	22.19
Oxygen consumed	168	.843	.1135	7.43
10-day oxygen demand	1,220	6.119	.2200	27.81
Average				16.43

[a] From: A study of the pollution and natural purification of the Ohio River, II, Public Health Bull. No. 143, Washington, 1924, Table 46, p. 77.

---

[2] Report on industrial wastes from the stock yards and packingtown in Chicago, 1914 and 1921. Sanitary District of Chicago, Chicago, Ill.

It is evident from these results that certain constituents of packing-house wastes are proportionately much greater in amount than others, as compared with domestic sewage. For instance, the oxygen demand contributed to the sewage by one animal killed is equivalent to the contribution of over 27 persons, while the free ammonia is equivalent to that from only 12.57 persons. The average of all these results indicates that the waste from each animal handled is equivalent to approximately the waste contributed by 16 persons. According to Table No. 10, the average daily number of animals passing through the packing industry during the course of the investigation was 36,867, hence the industrial wastes are reckoned as equivalent to the sewage from 605,700 people.

It is probable that the total nitrogen and oxygen demand constituents of industrial wastes are, for purposes of comparison, more representative measures of the polluting effects of these substances. By using the average of these two values as presented in Table No. 11, the wastes from each animal slaughtered are found to be equivalent to the domestic sewage from 25 persons; or, on this basis of comparison, the Chicago packing-house wastes are equivalent to a sewered population of 921,700.

By a similar procedure, the population equivalent of the wastes from all Chicago industries has been estimated as shown in Table No. 12, column A. Similar estimates of equivalent populations, computed on the basis of biological oxygen demand only, are given in column B. Figures in column C are estimates made by the Sanitary District of Chicago, as published in part 2 of the Chicago Industrial Wastes Report above mentioned.

TABLE No. 12.—*Population equivalent of Chicago sewage and industrial wastes*

	A	B	C
Packingtown wastes	921, 700	1, 025, 400	1, 000, 000
Tannery wastes	171, 700	66, 900	400, 000
Miscellaneous wastes	360, 300	598, 600	
Total population equivalent of all Chicago industrial wastes	1, 463, 700	1, 690, 900	1, 400, 000
Sewered population of Chicago contributing to main drainage canal	2, 834, 400	2, 834, 400	2, 757, 600
Total equivalent population of Chicago	4, 298, 100	4, 525, 300	4, 157, 600
Population equivalent of industrial wastes along main drainage canal	[1] 421, 900	421, 900	370, 000
Total population equivalent above station 292.0	4, 720, 000	4, 947, 200	4, 527, 600

[1] Based on oxygen demand only.

NOTE.—Column A. Equivalent population based on average of total nitrogen and 5-day oxygen demand. Column B. Equivalent population based on oxygen demand only. Column C. Estimates from report on industrial wastes from the stockyards and packingtown in Chicago, pt. 2, 1921, p. 7.

Since estimate A is the more conservative, the figure of 4,720,000, computed on this basis, has been used as representing the total population equivalent of the combined industrial wastes discharged to the main drainage canal above Lockport. This estimate is fairly close to that of the Sanitary District of Chicago (4,527,600) as presented in column C.

In a similar manner, the population equivalents of all the plants of each industry on the whole watershed have been computed, and these equivalents added to the actual population figures as derived in Table No. 6, to give a figure for the total population equivalent to the actual population plus the industrial wastes discharged above each sampling station on the river. This summation of population is presented in Table No. 13.

TABLE No. 13.—*Summary of actual sewered population on Illinois River watershed, with estimates of population equivalents of industrial wastes*

Sampling point	Actual sewered population	Population equivalents of industrial wastes	Total sewered population equivalent
292.0	2,834,351	1,885,600	4,719,951
285.8	2,935,733	1,911,320	4,847,053
277.6	2,935,733	1,911,320	4,847,053
263.2	3,006,588	1,911,320	4,917,908
247.3	3,006,588	1,949,410	4,955,998
239.9	3,008,495	2,041,790	5,050,285
226.8	3,103,377	2,044,560	5,147,937
196.0	3,146,453	2,045,510	5,191,963
179.0	3,150,076	2,045,990	5,196,066
166.1	3,150,076	2,045,990	5,196,066
153.5	3,223,001	2,552,870	5,775,871
147.9	3,226,762	2,698,450	5,925,212
120.1	3,229,445	2,698,450	5,927,895
100.8	3,247,813	2,698,450	5,946,263
88.6	3,304,565	2,820,940	6,125,505
76.7	3,376,991	2,820,940	6,197,931
42.9	3,387,711	2,820,940	6,208,651
30.9	3,387,711	2,820,940	6,208,651
25.7	3,390,531	2,820,940	6,211,471
At mouth of:			
Des Plaines	75,019	----------	75,019
Kankakee	48,331	----------	48,331
Fox	85,463	----------	85,463
Vermilion	13,178	----------	13,178
Mackinaw	2,682	----------	2,682
Spoon	19,452	----------	19,452
Sangamon	114,763	122,490	237,253
Crooked Creek	4,336	----------	4,336
Macoupin Creek	5,428	----------	5,428

It will be noted from this table that the total population equivalent of all the industrial wastes on the watershed is estimated at 2,820,900 or approximately 85 per cent of the actual sewered population; in other words, industrial wastes are responsible for over three-fourths as much pollution as is attributed to domestic sewage. Of the total amount of industrial waste, over 66 per cent is contributed by the main drainage canal, the remaining 34 per cent being accounted for by industries distributed throughout the rest of the area of the Illinois River watershed. Adding the population equivalent of industrial wastes to the actual sewered population, the result for the whole watershed is the equivalent of a sewered population of 6,211,500, of which 4,720,000, or more than 75 per cent, discharge through the Chicago Drainage Canal.

Other than wastes from the meat-packing industry, those of most importance from the standpoint of pollution of the river are contributed by tanneries, corn-products factories, and paper-pulp and strawboard mills. Distilleries, manufacturing alcohol, breweries, vegetable canneries, and creameries are also responsible for appreciable amounts of waste organic materials that reach the watercourse either direct or mixed with the domestic sewage. Miscellaneous industries of various kinds naturally contribute, in the aggregate, a considerable volume of pollution. Very few, if any, of these industrial wastes receive any treatment before discharge to the river. However, some of the more important of them, such as tannery and corn-products wastes, are being carefully studied by the Sanitary District of Chicago with a view to at least partial treatment before discharge to the main drainage canal.

CHAPTER III

HYDROMETRIC MEASUREMENTS

PURPOSE OF HYDROMETRIC STUDIES

The degree to which any stream is polluted by a given amount of waste is dependent upon the volume of receiving water or extent of dilution to which the wastes are subjected; and the extent of the change occurring in the polluted water between any two successive points in the channel is proportionate to the rate of change and the time required for the water to flow from one point to the other. For a quantitative study of pollution and of the rates of natural purification it is, therefore, essential to ascertain, for each stretch of the river under observation, the volume of the stream and the velocity of flow or time occupied in passing from one end of each section to the other.

In this study there were accordingly three principal groups of hydrometric determinations to be made for all conditions:

1. The rates of discharge of the main stream at each sampling station.
2. The rates of discharge of each principal tributary at its mouth.
3. The times of flow between the various sampling stations from which are derived the total times of flow from the uppermost to each successive station downstream.

DATA FROM WHICH CALCULATIONS WERE MADE

The hydrometric calculations were made from data of three classes—maps, river gauge heights, and discharge ratings. The existing data on these subjects were compiled from the records of the Engineer Corps of the United States Army, the United States Geological Survey, the United States Weather Bureau, the Sanitary District of Chicago, and the division of waterways of the State of Illinois.

MAPS

Two maps were used, one, the larger, showing the river and bottom lands on a large scale, the other showing the entire watershed on a smaller scale. The larger map, showing the topographic features, contours, and improvements of the bottom lands of the Illinois and Des Plaines Rivers, from Lockport, Ill., to the mouth of the Illinois River in 58 sheets on a scale of 1 inch = 600 feet, constitutes part of the report of a survey of the Illinois River made under the direction of a board of officers of the Corps of Engineers, United States Army, 1902–1904.[1] In this survey, on lines run normal to the river channel at intervals of about 500 feet, soundings about 50 feet apart were made of the stream and adjoining lakes. These soundings are referred to low water of 1901, the elevation of which is shown at various points with reference to Memphis datum. Elevations of contours and other features of the survey are also referred to Memphis datum, which has therefore been adopted as the base datum for our studies. The relation of the Memphis datum to various Mississippi Valley datum planes is shown in Appendix No. 1. The large-scale maps were used also for locating sampling stations and for measuring the backwater areas. Drainage areas were determined from post-route maps, as before explained.

GAUGE HEIGHTS

The gauges on the Illinois River selected for reference are shown in Table No. 14. Of these, 10 are maintained and read daily by the Corps of United States Army Engineers, 3 by the United States Weather Bureau, and 9 are maintained and read twice daily by the Sanitary District of Chicago. At Joliet, Ill., a Gurley continuous recording gauge is maintained by the United States Geological Survey, from which records the discharge may be accurately integrated, notwithstanding the rapidly and widely fluctuating stages caused by the opening and closing of gates at the Lockport power plant, about 2 miles upstream.

---

[1] Report upon survey for a navigable waterway from Lockport, Ill., to mouth of Illinois River. House of Representatives, Fifty-ninth Congress, first session. Document No. 263. Washington, Government Printing Office, 1905.

TABLE No. 14.—*Summarized description of Illinois River prisms*

Prism No.	Extent		Length of prism (miles)	Reference gauge				Tributary drainage area in square miles					Sampling stations
	From mile—	To mile—		Location		Maintained by—	Elevation of zero, Memphis datum	Directly tributary	From streams		Enters at mile—	Run-off per square mile assumed same as—	
				Mile	Place				Name of stream	Drainage area			
1	0.0	18.0	18.0	0.0	Grafton	U. S. Weather Bureau	410.96	93	Otter Creek	86	14.8	Macoupin Creek	
2	18.0	22.5	4.5	31.5	Kampsville Lock, lower.	U. S. Engineers	409.10	18				do.	
3	22.5	31.5	9.0	31.5	do.	do.	409.13	49	Macoupin Creek	944	23.0	do.	27.7, 30.9
4	31.5	52.0	20.5	43.2	Pearl	do.	410.70	198	Apple Creek Big Sandy	418 211	36.3 51.1	do.	31.8, 42.9
5A	52.0	77.6	25.6	77.6	La Grange Lock, lower.	do.	418.23	217	Mauvais Terre McGee	230 424	63.1 66.6	Crooked Creek	76.7
5B	77.6	83.3	5.7	77.6	La Grange Lock, upper.	do.	418.23	63	Indian Creek	286	78.8	do.	78.0
6	83.3	84.3	1.0	77.6	do.	do.	418.23	16	Crane Creek Crooked Creek	41 1,349	82.9 83.8	do.	84.0
7	84.3	96.5	12.2	88.8	Beardstown	do.	427.25	68	Sugar Creek	180	94.3	do.	88.6
8	96.5	98.5	2.0	88.8	do.	do.	427.25	9	Sangamon River	5,382	99.0	Sangamon River	
9	98.5	117.0	18.5	112.0	Bath	Chicago Sanitary District	433.46	161	Otter Creek	110	111.8	Spoon River	100.8
10	117.0	122.0	5.0	119.9	Havana	U. S. Engineers	431.67	36	Spoon River	1,812	120.6	do.	120.9
11	122.0	135.6	13.6	128.0	Liverpool	Chicago Sanitary District	428.30	122	Quiver River	254	122.2	do.	122.5
12	135.6	147.6	12.0	136.8	Copperas Creek Lock, upper.	U. S. Engineers	432.73	37	Copperas Creek	141	136.7	do.	
13	147.6	151.5	3.9	152.9	Pekin	do.	438.57	49	Mackinaw	1,174	147.7	do.	147.9
14	151.5	154.5	3.0	152.9	do.	do.	438.57	46				Mackinaw	153.5
15	154.5	160.0	5.5	159.2	Wesley City	Chicago Sanitary District	442.98	43	Kickapoo	318	160.6	do.	
16	160.0	164.0	4.0	165.0	Peoria	U. S. Engineers	435.82	74				do.	162.0
17	164.0	180.0	16.0	165.0	do.	do.	435.82	224				do.	166.1, 178.0
18	180.0	196.0	16.0	196.1	Henry Lock, lower.	do.	436.64	545				Vermilion	
19	196.0	210.3	14.3	196.1	do.	do.	436.64	153	Bureau Creek	490	209.0	Spoon	196.0
20	210.3	217.0	6.7	213.9	Depue	Chicago Sanitary District	439.75	77				do.	
21	217.0	227.0	10.0	223.4	Peru	U. S. Weather Bureau	440.01	110	Little Vermilion Vermilion River	121 1,261	225.6 226.5	Fox Vermilion	226.8
22	227.0	237.8	10.8	236.0	La Salle County Farm.	Chicago Sanitary District	452.05	143				do.	
23	237.8	240.8	3.0	239.6	Ottawa	do.	453.90	11	Fox River	2,580	239.7	Fox	239.8
24	240.8	247.2	6.4	239.6	do.	do.	453.90	23				do.	
25	247.2	259.9	12.7	252.8	Seneca	do.	465.70	157				do.	247.3
26	259.9	263.9	4.0	263.3	Morris	U. S. Weather Bureau	485.96	86	Mason River	507	263.4	Vermilion	263.2
27	263.9	272.5	8.6	270.7	Divine	Chicago Sanitary District	491.12	30	Ausable Creek	200	268.2	Fox	
28	272.5	273.5	1.0	270.7	do.	do.	491.12	3	Kankakee River	5,297	273.0	Kankakee	
29	273.5	287.0	13.5	277.7	Jackson Creek	do.	503.04	119	Dupage River	341	277.3	Fox	277.6, 285.8

NOTES.—Discharge rating stations were located at stations 88.6, 119.9, 162.0, 263.3, and 288.1. The discharge leaving prism No. 7 was taken the same as the rating station at Beardstown, mile 88.8. The discharge of prism No. 10 was considered equal to the discharge at the Havana rating station, mile 119.9. The Peoria rating station, mile 162.0, was located in prism No. 16. The discharge of prism No. 28 was considered equal to that of the Morris rating station, mile 263.3. The Joliet rating station, mile 288.1, was located above prism No. 29. Peoria Lake extends from mile 162.0 to 178.0 and is included in prisms Nos. 16 and 17. The city of Peoria adjoins prism No. 16.

Gauges on the main tributaries of the Illinois River are maintained by the United States Geological Survey and are read once daily. On tributaries where two or more gauging stations are maintained the station nearest the Illinois River was selected for reference. The tributaries having gauges and the locations of the rating stations are shown in Table No. 15.

TABLE No. 15.—*Relative location of principal tributaries of the Illinois River and their respective rating stations*

Name of tributary	Area of watershed (square miles)	Station of confluence in miles above Grafton	Side of channel	Location of rating station	Ratio of total drainage area to that above rating station
Des Plaines [1]	700	288.8	Right	Lemont	1.09
Kankakee	5,297	273.0	Left	Custer Park	1.08
Fox	2,580	239.7	Right	Wedron	1.03
Vermilion	1,261	226.5	Left	Streator	1.24
Mackinaw	1,174	147.7	do	Pekin	1.03
Spoon	1,812	120.6	Right	Seville	1.15
Sangamon	5,332	99.0	Left	Oakford	1.07
Crooked Creek	1,349	83.8	Right	Ripley	1.04
Macoupin Creek	944	23.0	Left	Kane	1.14

[1] Not including the Chicago River.

RATING STATIONS

Four rating curves, correlating gauge height and discharge of the Illinois River, located at Morris, Peoria, Havana, and Beardstown, Ill., in addition to the one previously mentioned at Joliet, were selected for the basis of discharge calculations of the main stream. These curves were obtained from three principal sources—the Sanitary District of Chicago, Corps of Engineers of United States Army, and United States Geological Survey. The locations of rating stations on the principal tributaries are shown in Table No. 15.

Discharge curves at most of these places had been established previously by one of the above organizations, but with the exception of those made by the Geological Survey the measurements had, for the most part, been made some years ago. The Geological Survey rating curves, having been more recently established and revised, were found to correspond well with measurements made by the Public Health Service in the course of this study, and the daily discharges as computed by the Geological Survey have therefore been used as the basic data of these hydrometric studies. Hydrographs of gauge height and discharge at the Morris, Peoria, and Beardstown stations are shown in Figure 3.

It was found necessary to establish new gauges and discharge stations on the Mackinaw River, Crooked Creek, and Macoupin Creek. This work was done with the cooperation of the Sanitary District of Chicago, the gauge readers being employed by the United States Geological Survey.

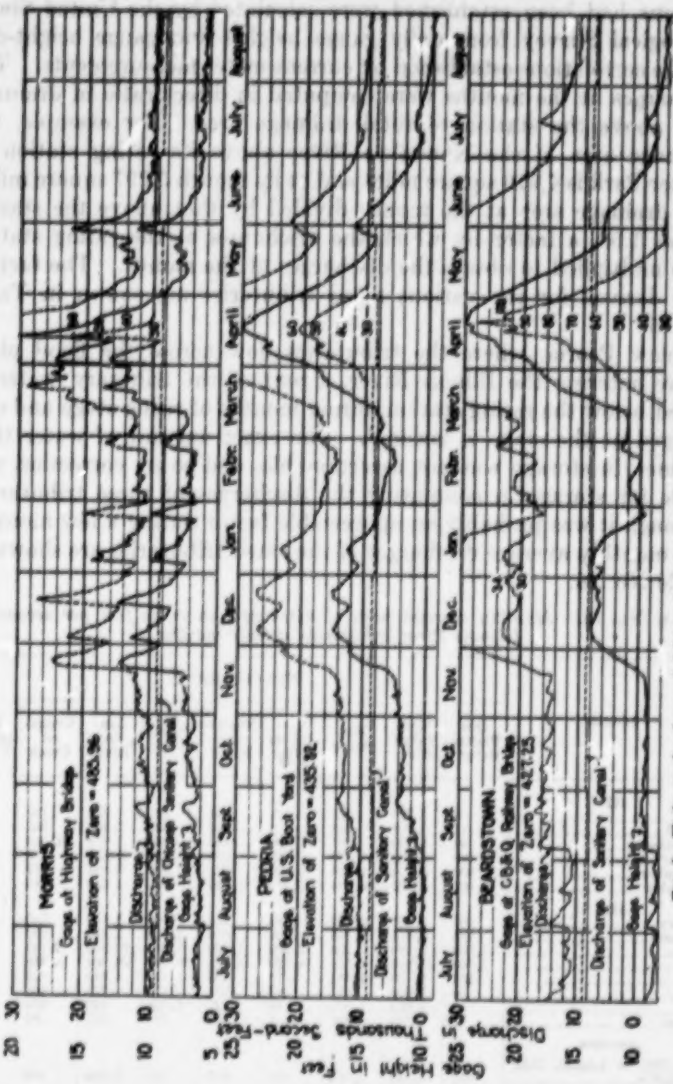


Fig. 3.—Hydrographs of gauge heights and discharge of the Illinois River, July, 1921, to August, 1922

METHODS OF CALCULATING DISCHARGE

DISCHARGES OF RATED TRIBUTARIES

The daily discharges at rating stations of tributaries on which such stations had been established were calculated by the United States Geological Survey from daily gauge heights and gauge height-discharge correlations established by current meter measurements. The discharges at the mouths were computed in direct ratio of drainage area above the station to total drainage area. For example, the drainage area of the Kankakee River above its rating station at Custer Park is 4,916 square miles and at its mouth 5,297 square miles. The drainage area at the mouth divided by that above the station equals 1.08, a factor by which the discharges at the rating station were multiplied to obtain the discharges at the mouth. The factors thus derived for the various rated tributaries are shown in Table No. 15.

Below Peoria, where the tributaries flow across the flood plain before entering the Illinois River, a part of the tributary water is stored below the rating station during months of rising stage and discharged as the stage is lowered. The exact amount of water thus retained in storage was not ascertainable, and so no correction was made for storage in computing the discharges of these tributaries, although it was probably an appreciable factor during a few months. The monthly average discharges of the rated tributaries are shown in Table No. 16.

TABLE No. 16.—*Monthly average rates of discharge, in cubic feet per second, of Illinois River tributaries at their mouths*

Month	Name of tributary								
	Des Plaines River [1]	Kankakee River	Fox River	Vermilion River	Mackinaw River	Spoon River	Sangamon River	Crooked Creek	Macoupin Creek
1921									
July	0	700	225	6	104	195	743	192	89
August	11	708	248	2	256	397	1,133	565	226
September	44	1,230	807	290	830	735	1,972	1,506	231
October	198	1,120	1,659	187	295	332	1,312	319	85
November	895	4,844	2,166	1,020	623	399	3,594	313	707
December	1,909	5,805	3,584	1,270	1,140	906	4,630	865	830
1922									
January	493	4,861	2,360	443	625	765	3,530	745	649
February	121	3,571	1,148	708	618	1,312	3,130	995	409
March	1,034	9,190	3,236	2,590	1,896	1,642	13,300	2,130	3,367
April	1,598	19,610	4,556	4,520	3,715	2,798	26,900	3,450	5,605
May	251	5,160	1,481	775	800	1,323	4,910	482	344
June	66	1,923	621	188	321	497	1,770	138	91
July	40	1,022	531	58	121	1,023	620	670	25
August	23	713	327	1	82	109	217	89	19
Averages									
July, 1921, to August, 1922, inclusive	547	4,340	1,632	861	827	881	4,840	870	910
September, 1921, to August, 1922, inclusive	532	4,946	1,864	1,004	936	978	5,480	935	1,035
Summer months [2]	32	1,049	460	95	277	492	1,076	526	114
Winter months [3]	814	5,934	2,557	1,245	1,070	1,122	6,145	1,064	1,314

[1] Discharge of Des Plaines River at Lemont, Ill.

[2] Summer months include July, August, and September, 1921, and June, July, and August, 1922.

[3] Winter months include December, 1921, and January, February, and March, 1922

DISCHARGES OF UNRATED TRIBUTARIES

The most important of the smaller tributaries on which rating stations were not located are listed in Table No. 17. The discharges of these streams were estimated by assuming that the run-off per square mile of drainage area was equal to that of the nearest rated tributary during the same period.

Table No. 17.—*Smaller tributaries of the Illinois River*

Name of tributary	Area of watershed (square miles)	Station of confluence, miles above Grafton	Side of channel
Du Page River	341	277.3	Right.
Au Sable Creek	300	269.2	Do.
Mazon Creek	507	263.4	Left.
Little Vermilion River	121	225.6	Right.
Bureau Creek	490	206.0	Do.
Kickapoo Creek	318	159.6	Do.
Copperas Creek	141	136.7	Do.
Quiver River	254	122.2	Left.
Otter Creek	110	111.8	Right.
Sugar Creek	150	94.3	Do.
Crane Creek	41	82.9	Do.
Indian Creek	256	75.8	Left.
McGee Creek	434	66.6	Right.
Mauvais Terre Creek	280	62.1	Left.
Big Sandy Creek	211	51.1	Do.
Apple Creek	418	35.3	Do.
Otter Creek	95	14.8	Do.
Total	4,266	....	

RATES OF DISCHARGE AT SAMPLING STATIONS

The daily discharge at the rating stations of the Illinois River being available from the Geological Survey, the next procedure was to determine the rates of discharge at each of the various sampling stations throughout the stream. This was done by one of two methods, depending on local conditions.

In the first or numerical method the entire river channel was divided into prisms, varying in length from 1 mile to over 20 miles. The limits of prisms were in general taken at the location of sampling stations, confluence of important tributaries, or at points of definite change in the channel altering the depth, width, or slope of the water surface. It was generally desirable to have a prism terminate at a sampling station for convenience in referring calculations of discharge and velocity to the sampling station. Where large tributaries entered, short prisms were taken extending from a point just above to a point a short distance below the junction. Reasonably uniform channel characteristics were essential for each prism to insure as little variation as practicable in flow conditions throughout the section.

The limits of all prisms were plotted on a map of the Illinois River watershed and the boundaries of the drainage area of each section determined in such a way that the portion draining through the principal tributary streams could be measured separately from that draining more directly to the Illinois River. A reference gauge was selected for each prism to which all gauge height correlations for that stretch could be referred. A description of the prisms, showing the location, tributary drainage area, and reference gauge of each, is given in Table No. 14.

Discharges of the various prisms were calculated by a process of summation, working downstream from one rating station to the next below, when the discharges as given by the lower rating station were used in proceeding on from that point. Usually the discharges at the lower rating station as computed by the summation process from the upper rating station checked within 10 per cent of those given by the discharge curve at the lower rating station, but occasionally larger variations occurred.

The method may best be described in detail by an illustration of the procedure. Prism No. 29 is the farthest upstream, extending from mile 287.0 to mile 273.5. An unrated tributary, the Dupage River, with a drainage area of 341 square miles, enters at mile 277.3 and in addition there are 119 square miles more directly tributary. Sampling stations are located at 277.6 and 285.8. The run-off per square mile of the Dupage watershed was taken as equal to that of the Fox drainage area, the nearest rated tributary. In the same way the unit run-off from the 119 square miles directly tributary was assumed to be equal to that of the Fox. The daily discharges were thus computed and tabulated for each month as illsutrated in Table No. 18. The discharge leaving prism 29 would be the sum of that entering plus the computed discharge from the Dupage River and from the drainage area adjacent to the prism.

TABLE No. 18.—*Discharge and time-of-flow computations*

[Prism No. 29, miles 287.0-273.5; length, 13.5 miles; reference gauge at mile, 277.7; Jackson Creek gauge elevation of zero 500.4]

1922	Gauge height	Flow in second-feet				Mean cross-sectional area of prism	1 / Velocity (in feet per second)	Time of flow in hours from station 287.0 to station 273.5
		Entering	From Dupage River, 341 square miles	From adjacent area, 119 square miles	Average for prism			
Ap. 1	7.70	14,400	864	301	14,900	3,870	0.261	5.17
2	6.85	14,400	767	266	14,700	3,400	.251	4.87
3	6.55	14,400	723	245	14,700	3,400	.231	4.07
4	6.25	13,600	762	243	13,900	3,360	.263	5.19
5	6.25	13,300	675	226	13,600	3,330	.245	4.65
6	4.90	12,000	648	226	12,300	3,000	.254	4.69
7	4.70	11,300	646	226	11,300	3,030	.265	4.87
28	2.05	7,400	315	124	7,600	2,316	.304	6.00
29	1.70	7,100	306	118	7,200	2,450	.312	6.18
30	1.90	7,100	315	110	7,300	2,290	.311	6.15

The mean discharge throughout the length of the prism was computed on the assumption that the run-off from the drainage area directly adjacent was uniformly distributed along the prism, so that one-half of the computed total inflow was added to the discharge entering at the upper end. To this sum was also added a fractional amount of the discharge from tributary streams based on the ratio of the distance that such contribution flowed through the prism to the entire prism length. Thus, in prism 20, which is 13.5 miles in length, the Dupage enters 3.8 miles from the lower end. The mean discharge throughout the prism for each day was then obtained by adding, to the discharge entering, one-half of the computed discharge from the adjacent drainage area and also $\frac{3.8}{13.5}$ of the discharge of the Dupage River.

Daily mean discharges for each prism were computed for periods of several months, so selected that river stages covering all ranges from highest to lowest were included. From these daily discharges gauge height-discharge curves for the sampling stations were plotted and rating tables made up from the curves. Since the sampling stations were usually located at or near the upper or lower limits of prisms, the flow past the sampling station was taken as equivalent to the flow entering or leaving the prism, as the case might be. In special cases, where a sampling station was located at some intermediate point in the prism length, an adjustment of the computed flow was made proportional to the percentage of the inflow entering above the point. The final daily discharge at the sampling station for each day was taken as the quantity given in the rating table corresponding to the gauge height of the reference gauge for such day. Monthly average discharges were computed from a summation of the daily discharges of the month.

The results given by this method were quite consistent for stations above La Salle, but exhibited certain inconsistencies for stations between La Salle and Peoria, as well as for parts of the lower river. The river channel undergoes marked changes below La Salle, where the slope of the water surface flattens to an average of about 1 inch per mile and the valley widens, forming a flood plain varying in width from 1½ to 3 miles which contains many lakes and sloughs. In periods of sudden rise of river stage these lands become flooded and, in effect, act as immense equalizing reservoirs, storing water during rising stages and gradually releasing it on falling stages. For example, during November, 1921, the river stage at Peoria changed from a gauge height 12.60 to 16.30, a rise of 3.7 feet. The consequent flooding of lowlands between La Salle and Peoria during this month, as actually determined from map measurements of areas inundated, accounted for a volume of retained water equivalent to a rate of flow of about 2,800 cubic feet per second, or over 17 per cent of the monthly average discharge of 16,100 second-feet at Peoria. Similarly, during March, 1922, water was being stored above Peoria at the rate of 4,500 second-feet when the average monthly flow was 23,100 second-feet, and, conversely, during May, 1922, previously stored water from these flooded areas was being discharged at a rate corresponding to 3,900 cubic feet per second when the monthly average flow at Peoria was 23,600 second-feet.

In consequence of this alternating condition of storage in or discharge from the lowlands, there is no constant relation between the discharge below the storage area and the total run-off above. For example, the discharge at Peoria should, under ordinary circumstances, be equal to the discharge at Morris, plus the combined discharge of the intervening rated tributaries (Fox and Vermilion) plus a run-off from the drainage area of unrated tributaries at the same rate as for the watersheds of the Fox or Vermilion. However, because of storage taking place between Morris and Peoria, the observed discharge at the latter station may be materially less than this total, or, at a falling river stage, when stored water is being released, may be greater. It therefore becomes necessary to take into account the actual condition, whether of storage or release of surplus water, in calculating discharges for stations intermediate between Morris and Peoria.

The solution finally adopted for determining discharges at sampling stations was essentially a scheme of interpolating, or, in some cases, extrapolating, between rating stations in proportion to the contributing drainage area. As a matter of convenience the computations were made graphically.

The discharges at the sampling stations were determined quite independently of the gauge heights of the reference gauges of the sampling stations, and the effect of storage was taken into account approximately. The computations were made on two separate graphs, the stations above Peoria on one and those below Peoria on the other. A specimen month of the former is shown in Figure 4.

DISCHARGES AT SAMPLING STATIONS ABOVE PEORIA

Above Peoria all large tributaries enter the Illinois River above the point where appreciable storage begins. Moreover, the channels of tributaries, between their rating stations and their mouths, are confined by steep slopes with practically no flood plains on which storage of tributary water might occur. It was assumed that the monthly average run-off per square mile was uniform over the drainage area lying between two consecutive Illinois River rating stations, the rated tributaries excluded. The total drainage areas between station 287.0, which is the upper limit of prism 29, and the various sampling and rating stations were computed from the areas as measured on the post-route map and used in the previously described method of calculation. Drainage areas were plotted as abscissæ and discharges as ordinates. The sampling and rating stations were plotted on the chart according to the extent of drainage area above each station, excluding the watershed areas of the three rated tributaries Kankakee, Fox, and Vermilion Rivers.

Monthly average discharges at the three rating stations—at Joliet, located at station 287.0; Morris, station 263.2; and Peoria, station 162.0—were computed from their respective rating curves, as were also monthly average discharges of the Kankakee, Fox, and Vermilion Rivers. Station 287.0, the upper limit of prism No. 29, was taken as the starting point, where the discharges were assumed to be equal to those at the Joliet rating station, which is about 2 miles upstream. The monthly average discharges of the Joliet rating station were plotted on the ordinate of station 287.0. The Kankakee River unites with the Des Plaines between Joliet and Morris, the location of the next rating station. Therefore, on the ordinate of station 263.2, at Morris, were plotted the differences between the respective monthly average discharges of Morris rating station and of the Kankakee River.

Since there was no storage between Joliet and Morris, the corresponding points at stations 287.0 and 263.2 were joined by straight lines and the monthly average discharges of intermediate sampling stations read directly from the chart. Had there been a sampling station between the mouth of the Kankakee and Morris, the computed flow at such station would have been the sum of the Kankakee discharge and the discharge as taken from the chart.

Between Morris and Peoria the effect of storage below La Salle necessitated some changes in methods used above Morris. The monthly average total discharges at the Morris rating station were plotted on the ordinate for Morris. The combined discharges of the Fox and Vermilion Rivers were deducted from the corresponding monthly mean discharges at Peoria and the remainders plotted at the Peoria station. If the gauge-height change during the month was small, the respective points at Morris and Peoria were joined by straight lines, since the effect of storage was negligible.

For months during which gauge-height change exceeded 2.0 feet the effect of storage on the rate of flow was taken into account by an approximate method. Between Morris and Peoria there are six sampling stations, located, respectively, at 247.3, 239.9, 226.8, 196.0, 179.0, and 166.1 miles above Grafton. Storage begins at about mile 217 and continues in varying amounts to mile 162, where the Peoria rating station is located. The stations upstream from mile 217 are not affected appreciably by storage.

The discharge lines were produced from Morris to a point below mile 217 at a slope equal to that of the corresponding line between Joliet and Morris. This was equivalent to assuming that the run-off

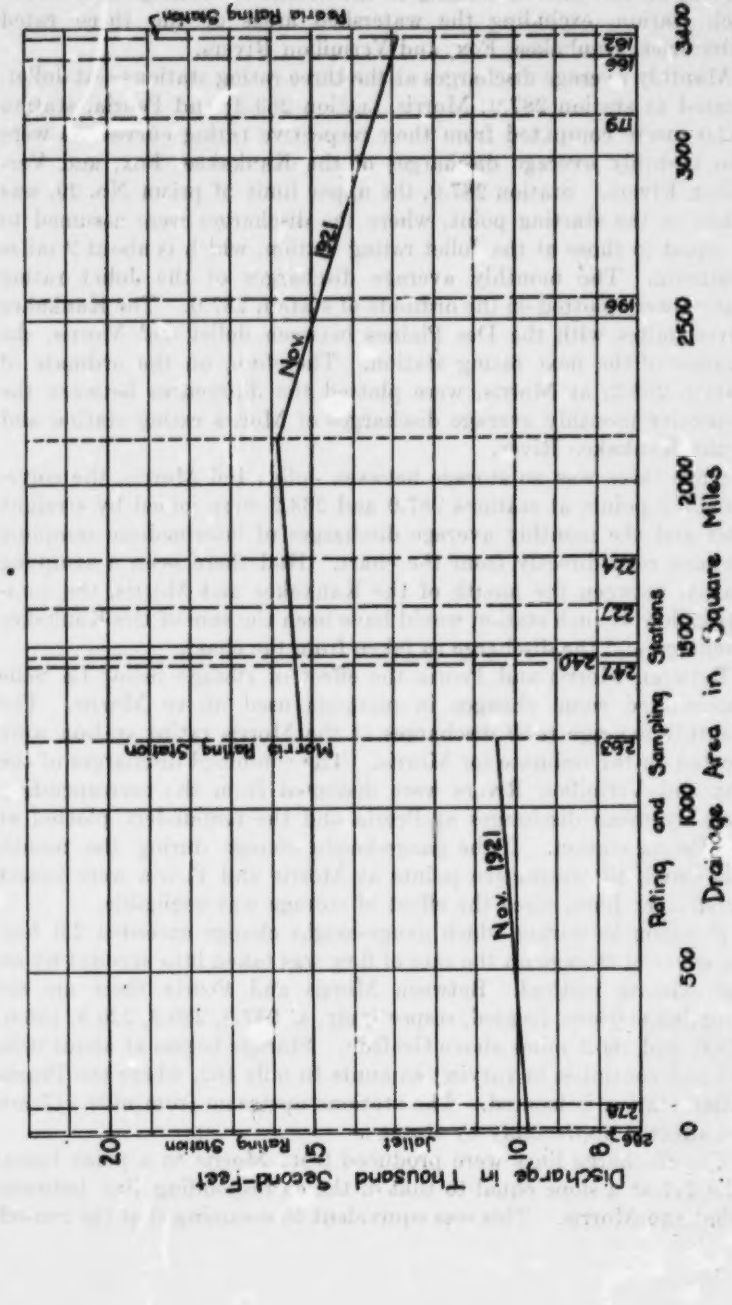


Fig. 4.—Specimen diagram of discharges at sampling stations above Peoria

per square mile from adjacent land for some 40 miles below Morris was equal to that between Morris and Joliet. The produced line was broken below mile 217 and drawn from there straight to the point for that month plotted on the ordinate of the Peoria rating station.

The position at which the lines were broken was determined by the ratio of storage capacities above and below Henry, station 196.0. The average fall of the water surface between station 196.0 and 162.0 is less than 1 foot. Storage capacities were determined by measuring storage areas on the large-scale contour map made by the Corps of Engineers, United States Army. To compensate for the slope of the water surface, slight divergence from the contour was made by estimation. Areas for high-water and medium stages were measured, and for each condition the ratio of the storage above station 196.0 to that between station 196 and 162 was determined. Thus, for a gauge height of 24 feet (high water) at Peoria, station 162.0, the storage rate is approximately 420 cubic feet per second per foot rise in gauge height per month of 30 days between miles 217 and 196, and between miles 196 and 162 it is approximately 600 second-feet, or a ratio of $\frac{420}{600}=0.7$. For a gauge height of 14 feet (medium stage) at Peoria, storage rates in the same sections above and below station 196.0 are approximately 280 and 470 second-feet, respectively, or a ratio of $\frac{280}{470}=0.6$. Since, during months when the storage effect was appreciable, the gauge heights at Peoria ranged within the limits 14 to 24 feet, the ratio of storage rate above station 196.0 to that below during any month probably was not less than 0.6 or more than 0.7. The average, 0.65, was used for all months, since the maximum difference in the final discharge figure by using 0.65 in place of 0.6 or 0.7 never would exceed 0.3 per cent. The ordinate on which the discharge lines were broken was therefore drawn on the chart at a distance upstream from station 196.0 equal to 0.65 of the plotted distance between stations 196.0 and 162.0.

The method used may best be explained by illustrating its application to a concrete example. In November, 1921, with a rising river stage, the mean discharges observed were:

(1) At Joliet, 9,750 cubic feet per second;
(2) Kankakee River, 4,844 cubic feet per second;
(3) At Morris, 15,300 cubic feet per second,

and hence the inflow from unrated tributaries between Joliet and Morris $= (3) - [(2) + (1)] = 710$ cubic feet per second.

(4) At Peoria, 16,100 cubic feet per second;
(5) Fox River, 2,166 cubic feet per second;
(6) Vermilion River, 1,020 cubic feet per second.

Now, the discharge at Peoria, excluding that of the Fox and Vermilion—that is, (4)−[(5)+(6)], or 12,914 second-feet—should exceed the discharge at Morris by the amount of inflow of unrated tributaries between Morris and Peoria. Actually, the discharge at Peoria (12,914 second-feet) when thus reduced is less than that at Morris (15,300 second-feet), indicating that storage has been taking place. Referring now to the graph (fig. 4), in which the drainage areas above sampling stations and rating stations, exclusive of rated tributaries, are plotted as abscissæ and discharges as ordinates, the discharges of 9,750 second-feet at Joliet rating station and of 10,456 second-feet at Morris (=Morris discharge minus Kankakee) are plotted on their respective ordinates. These points, connected by a straight line, give the rate of increase in volume due to direct inflow.

This same rate of increase is applied to the discharge below Morris by extending the line which starts from the total Morris discharge, parallel to the Joliet-Morris rate line, until it meets the line where storage begins as represented by the dotted line, the location of which was previously described. From this latter point a straight line is drawn to the plotted discharge at Peoria, which is the Peoria measured discharge less that of the rated tributaries, Fox and Vermilion. Ordinates below the line thus described then represent average discharges at the respective sampling stations for the month, exclusive of that from the two rated tributaries. Hence the total discharge at any sampling station below Morris is obtained by adding to its ordinate the proper discharge of the rated tributaries, Fox and Vermilion, providing one or both enter the river above the sampling station under consideration.

Since discharge from storage is only a reversal of the storage process, the method is likewise applicable to that condition and is indicated by a rising instead of a falling slope of the line connecting the ordinates representing the limits of the storage area.

DISCHARGES AT SAMPLING STATIONS BELOW PEORIA

Below Peoria the flood plain ranges from 3 to 7 miles in width and in its natural state contained many lakes and sloughs. Much of the bottom land is now inclosed by levees and drained by pumping, the natural storage formerly provided by the land now reclaimed being eliminated except during very high water, such as occurred in April, 1922, when many levees failed.

Above Peoria the main tributaries enter the Illinois River above the point where effective storage begins, and hence the rate at which water from the tributaries enters the Illinois River is entirely independent of the storage factor. In computing the rate of discharge at points where storage was effective, no error was introduced by deducting the tributary discharges before making the calculations and then adding them on to get the total flow. If the tributary discharges had been included while making the calculations the discharge lines would have been parallel to their present location but raised in each instance an amount equal to the discharge of the tributary.

Below Peoria the tributaries flow over the flood plain of the Illinois River before reaching the point of confluence. In times of rising stage much of the tributary discharge probably is stored near its own mouth before reaching the Illinois River proper. In computing the discharges of the tributaries, this fact was not taken into account, because there were no means available for determining the amount of storage that occurred between the rating station of the tributary and its mouth. Thus, during the month of November, 1921, there was created near the mouth of the Sangamon River a storage space capable of holding an amount of water not less than 30 per cent of the total Sangamon flow for the month. The part of this storage space that was filled by Sangamon River water and the part filled by water of the Illinois River is indeterminate and would likely depend largely on the relative rates at which the Sangamon and Illinois Rivers rose.

It would not be correct to assume that the run-off from the adjacent area between Havana and Beardstown was equal to the difference between the rated discharge at Havana and that at Beardstown with the computed Sangamon discharge deducted. During months of rising stage, only a part of the computed Sangamon River discharge would enter the Illinois River, and so only a part, the exact amount being indeterminate, should be deducted from the discharge at Beardstown before interpolating between Havana and Beardstown for flow at intermediate points. During months of falling stage the converse would be true. Since the part to be deducted is indeterminate, it is obvious that the method of computing discharges used for stations above Peoria could not be used below Peoria, where the discharges of the tributaries are affected by storage below the tributary rating stations. Some modification in the method was therefore necessary.

If the monthly average run-off were assumed uniform for the entire drainage area, including the tributaries, between two rating stations, and the entire area were included on the chart in locating the various sampling and rating stations, then the factor of storage within any tributary would be eliminated automatically. Storage capacity near the mouth of a tributary so located that it might be supplied with water either from the main stream or the tributary would tend to justify this assumption.

Using the Sangamon River again for illustration and considering interpolation between the rating stations at Havana and Beardstown, there are three possibilities—the rate of run-off per square mile of the Sangamon watershed must be equal to, greater than, or less than the rate of run-off from the adjacent watershed between Havana and Beardstown. If the rates of run-off are equal, then the assumption of equal run-offs is exactly correct. If the rate of run-off from the Sangamon River watershed is greater than that from the land adjacent to the Illinois River, then a greater proportion of the Sangamon River water will be held in storage and the effective flow reaching the Illinois River will be decreased, tending to bring the effective rates of run-off more nearly equal. If the rate of run-off from the Sangamon River watershed is less than that from the land adjacent to the Illinois River, then a greater proportion of the Illinois River water will be held in storage and its effective run-off will be decreased, tending in this case also to equalize the effective rates of run-off. Since the actual variation between the rates of run-off from the tributary watershed and adjacent land was small and since storage had an equalizing effect, the error resulting from the assumption of equal rates of run-off would probably be slight.

In computing the discharges at sampling stations below Peoria it was assumed that the monthly average rate of run-off per square mile was uniform over the entire watershed lying between two rating stations. Above Peoria the discharges and areas of the rated tributaries were excluded from the graph; below Peoria they were included. With this change, computations were made graphically, as shown in Figure 4, for the upper river.

Interpolations were made from the rating stations at Peoria, Havana, and Beardstown. The monthly average discharges at these three rating stations were plotted on their respective ordinates and straight lines then drawn between the corresponding points at Peoria and Havana and between Havana and Beardstown. The monthly average discharges at the various sampling stations were taken from the chart and are tabulated in Table No. 19.

TABLE No. 19.—*Monthly average discharge, in cubic feet per second, of the Illinois River at the various sampling stations*

Month	Sampling stations								
	292	286	278	263	247	240	227	224	196
1921									
July	8,760	8,560	8,570	9,120	9,210	9,220	9,495	....	9,860
August	8,460	8,270	8,280	9,130	9,200	9,200	9,480	....	9,750
September	8,230	8,080	8,110	9,920	10,000	10,000	10,900	....	11,500
October	8,540	8,780	8,810	10,500	10,500	10,600	12,300	....	12,600
November	8,870	9,750	9,790	15,300	15,400	15,500	17,800	....	17,900
December	8,670	10,400	10,500	17,900	18,100	18,100	21,900	....	24,000
1922									
January	8,310	8,700	8,720	14,000	14,100	14,100	16,500	16,900	15,200
February	8,380	8,330	8,330	12,300	12,500	12,500	13,700	14,600	15,200
March	8,740	9,780	9,820	19,900	20,100	20,100	23,400	26,100	25,100
April	8,480	10,200	10,400	23,200	23,800	24,000	39,000	....	45,700
May	8,910	9,010	9,070	15,200	15,400	15,400	17,000	....	20,200
June	9,370	9,250	9,280	11,800	11,900	11,900	12,600	....	14,400
July	8,850	8,696	8,730	10,300	10,400	10,400	10,900	....	11,320
August	8,520	8,360	8,390	9,660	9,670	9,670	10,000	....	10,100
Averages									
July, 1921, to August, 1922, inclusive	8,649	9,012	9,057	14,160	14,290	14,320	16,050	....	17,540
September, 1921, to August, 1922, inclusive	8,650	9,110	9,162	15,000	15,156	15,190	17,160	....	18,850
Summer months [1]	8,698	8,536	8,560	9,988	10,063	10,065	10,412	....	11,155
Winter months [2]	8,525	9,302	9,342	16,025	16,200	16,200	18,875	....	20,625

[1] Summer months include July, August, and September, 1921, and June, July, and August, 1922.

[2] Winter months include December, 1921, and January, February, and March, 1922.

Table No. 19.—*Monthly average discharge, in cubic feet per second, of the Illinois River at the various sampling stations*—Continued

Month	Sampling stations							
	179	166	162	153	148	122	121	101
1921								
July	10,000	10,100	10,100	10,100	10,200	10,300	10,400	10,700
August	9,800	9,960	9,960	10,000	10,000	10,100	10,100	10,300
September	11,700	11,800	11,800	11,900	11,900	12,100	12,200	12,600
October	12,800	12,800	12,800	12,900	12,900	13,200	13,300	13,800
November	16,600	16,100	16,100	16,100	16,200	16,300	16,300	16,600
December	24,600	24,900	24,900	25,100	25,200	26,100	26,300	27,700
1922								
January	19,500	20,100	20,100	20,500	20,600	22,000	22,300	24,200
February	15,600	15,800	15,800	16,100	16,100	17,100	17,300	18,600
March	23,700	23,100	23,100	23,400	23,500	24,600	24,800	26,500
April	46,700	47,200	47,200	47,800	48,000	50,200	50,600	54,700
May	22,600	23,600	23,600	24,400	24,600	27,400	28,000	32,200
June	15,900	16,500	16,500	16,900	17,000	18,300	18,600	20,500
July	11,420	11,500	11,500	11,700	11,700	12,300	12,400	13,200
August	10,100	10,100	10,100	10,100	10,100	10,200	10,200	10,400
Averages								
July, 1921, to August, 1922, inclusive	17,930	18,110	18,110	18,360	18,430	19,300	19,490	20,860
September, 1921, to August, 1922, inclusive	19,270	19,456	19,456	19,741	19,810	20,816	21,025	22,580
Summer months [1]	11,502	11,660	11,660	11,783	11,817	12,267	12,317	12,960
Winter months [2]	20,850	20,975	20,975	21,275	21,350	22,450	22,675	24,250

Month	Sampling stations							
	89	84	78	77	43	32	31	26
1921								
July	11,800	11,800	12,100	12,100	12,300	12,400	12,400	12,400
August	11,700	11,700	12,000	12,000	12,300	12,400	12,400	12,400
September	15,000	15,000	15,500	15,600	16,000	....	16,200	16,200
October	15,100	15,100	15,500	15,500	15,800	....	15,900	15,900
November	17,800	17,800	18,100	18,100	18,300	....	18,400	18,400
December	31,600	....	32,700	32,900	33,700	....	34,100	34,100
1922								
January	26,800	....	27,900	28,100	28,900	....	29,300	29,300
February	20,400	....	21,200	21,300	21,900	....	22,100	22,100
March	33,400	....	35,200	35,500	36,700	....	37,200	37,200
April	79,900	....	84,800	85,600	89,400	....	91,200	91,200
May	45,000	....	48,700	49,200	51,800	....	53,000	53,000
June	23,700	....	24,900	25,100	26,000	....	26,400	26,400
July	15,000	....	15,600	15,700	16,100	....	16,300	16,300
August	11,600	....	11,900	11,900	12,100	....	12,200	12,200
Averages								
July, 1921, to August, 1922, inclusive	25,630	25,630	26,860	27,040	27,950	....	28,360	28,360
September, 1921, to August, 1922, inclusive	27,941	....	29,333	29,540	30,560	....	31,025	31,025
Summer months [1]	14,800	....	15,333	15,400	15,800	....	15,983	15,983
Winter months [2]	28,050	....	29,250	29,450	30,300	....	30,675	30,675

[1] Summer months include July, August, and September, 1921, and June, July, and August, 1922.
[2] Winter months include December, 1921, and January, February, and March, 1922.

For the purpose of analyzing the results obtained by the method just described, the discharges of the Sangamon River and of the Illinois River at stations from Havana to Beardstown were placed in Table No. 20. The Havana rating station is located at mile 119.9 and the Beardstown station at 88.6. Sampling station 100.8 is upstream from the mouth of the Sangamon River. The drainage area of the Sangamon River is 5,332 square miles. The area directly

tributary to this stretch, being very small in comparison with that of the Sangamon, the slight discharge from it was not considered in the table. Since the Sangamon River is by far the largest tributary below Peoria, it seems probable that the error resulting from the assumption of uniform run-off would be greatest in the reach of the Illinois River affected by that stream.

TABLE No. 20.—*Analysis of monthly average rates of discharge at certain sampling stations of the Illinois River*

Date	Monthly average discharge in cubic feet per second						Per cent variation $\frac{(7)}{(6)}$%	Gauge height at Beardstown	
	At station 119.9	At station 100.8	Sangamon	(3)+(4)	At station 88.6	(6)−(5)		Change during month	Reading on first day of month
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1921									
July	10,600	10,700	743	11,443	11,800	+357	+3.0	−1.0	9.10
August	10,200	10,300	1,133	11,433	11,700	+367	+3.1	.0	8.10
September	12,450	12,600	1,972	14,572	15,000	+428	+2.8	+1.25	8.10
October	13,700	13,800	1,312	15,112	15,100	−12	−.1	−.15	9.35
November	16,500	16,600	3,594	20,194	17,800	−2,396	−12.4	+3.80	9.20
December	27,500	27,700	4,630	32,330	31,600	−670	−2.1	+.58	13.00
1922									
January	24,100	24,300	3,520	27,720	26,800	−920	−3.4	−3.60	13.58
February	18,500	18,600	3,130	21,730	20,400	−1,330	−6.5	+1.22	9.98
March	26,200	26,500	13,300	39,800	33,400	−6,400	−19.2	+7.88	11.20
April	53,400	54,700	26,900	81,600	79,900	−1,700	−2.1	+3.30	19.08
May	31,400	32,200	4,910	37,110	45,000	+7,890	+17.5	−8.91	22.38
June	20,300	20,500	1,770	22,270	23,700	+1,430	+6.0	−3.97	13.47
July	13,100	13,200	620	13,820	15,000	+1,180	+7.9	−.90	9.50
August	10,300	10,400	217	10,617	11,600	+983	+8.5	−.50	8.60
September									8.10
Average	20,590	20,860	4,840	25,700	25,630	−70	−.27	−.07	

Neglecting the small discharge from the adjacent area, it is obvious that if there had been no storage the discharge at Beardstown would equal that at station 100.8 plus the discharge of the Sangamon River. In the table the monthly average discharges of the Sangamon River (column 4) were added to the discharges at station 100.8 (column 3), the sum (column 5) subtracted from the discharge at the Beardstown rating station (column 6), and the difference recorded in column 7. Had there been no error in the ratings and no storage effect, the differences recorded in column 7 would have been zero in each case. The ratio in percentage of the difference (column 7) to the discharge at Beardstown (column 6) was recorded in column 8.

In column 9 is given the change in gauge height at the Beardstown gauge during the month. Manifestly the effect of storage is a function of the magnitude of the change in river stage. With no gauge height change the effect of storage would be zero. With a rising stage water would be held in storage in the backwater lakes, and the discharge at Beardstown should be less than the sum of the discharges at 100.8 and of the Sangamon, and hence the percentage variation should have a negative sign. Conversely, with a falling stage the sign should be positive.

By inspection of columns 8 and 9 it will be seen that the months of greatest gauge height change are also the months of greatest percentage variation. It may be noted, further, that in the months in which the gauge height variation was over 5 per cent the percentage variation has the proper sign—that is, a plus sign for a drop in stage and a minus sign for a rise. This fact indicates quite clearly that natural storage was an important cause of variation. During the months that the gauge height rose—November, 1921, and March, 1922—water was being held in storage and the discharge at Beardstown was less than the discharge at station 100.8 plus the discharge of the Sangamon, as shown by the negative variation. During the months that the gauge height fell (May and June, 1922) water was flowing out of storage, thereby increasing the discharge at Beardstown a greater amount than the points above, and the percentage variation was positive. The results for the months of January, July, and August, 1922, are slightly erratic. The irregularity of the January figures may be due partly to the ice on the backwaters and the main channel. The variations in the other months do not exceed what might be expected in stream ratings. During April, 1922, the river rose to a very high stage, flooding many levee districts and spreading over wide areas of bottom lands. The discharge at Beardstown during this month could not be determined with precision. Over the 14 months of observation—July, 1921, to August, 1922—the average percentage variation was 0.27, which indicates that in the long run the assumption of uniform run-off was not far amiss. Since the discharge figures at the rating stations may be in error 5 per cent, more or less, it is thought that the method used for interpolating the discharge of intermediate stations is sufficiently exact.

TIME OF FLOW BETWEEN SAMPLING STATIONS

Times of flow through individual prisms were computed from mean velocities which were determined by application of the fundamental relationship,

$$Q = av \text{ or } v = \frac{Q}{a},$$

that is, by dividing the mean discharge of the prism by the mean cross-sectional area. These times were then added together in the proper sequence to obtain the times between sampling stations.

The method of determining the average discharges of the prisms by the first or numerical method has already been described. (See p. 34.) Discharges thus determined were used in the calculations of velocity and time of flow, rather than discharges ascertained by the second or proportional method, because the wetted areas are computed from the same gauge-height data as are the discharges by the former method.

To determine mean areas of wetted cross sections, sections of the channel were plotted from the soundings and contours shown on the large-scale map made by the Corps of Engineers, United States Army, from the survey of 1904. Three or four sections per mile of stream length were plotted, assuming the water surface to be level throughout the length of the prism. The wetted areas were then measured by planimeter for each interval in river stage of 2½ feet between high and low water. From these measurements the average cross-sectional areas for each prism at successive river stages were computed and plotted in relation to elevation or gauge height of the reference gauge of the prism, giving a series of gauge height-area curves with the water surface assumed level.

It was necessary to apply a correction to these curves in order to obtain a revised gauge height curve for each prism for the water surface sloping as shown by the profile. The mean slope of the water surface was determined by correlating the gauge heights of successive reference gauges and plotting the profiles from these correlations. The correction of the gauge height-area curve was then made by adjusting the areas of the longitudinal sections of each prism as shown by its longitudinal profile.

The method in detail can best be explained by a concrete example. Prism No. 27, extending from mile 272.5 to 263.9, has its reference gauge located at mile 270.7, or 6.8 miles above the lower end and 1.8 miles below the upper end. The gauge height-area curve is shown in Figure 5 and the profile in Figure 6.

The water-surface profile lines as determined from correlations of the reference gauges of prisms, both above and below, with that of prism No. 27 were drawn through points of convenient elevation at the reference gauge for every 2.5 feet elevation. (See fig. 6.) Thus, for an elevation of 500 feet at the reference gauge the mean elevation of the water surface at the lower end of the prism is 497.5 and at the upper end 502.0 feet. From this it may be determined that the area below a level plane through elevation 499.2 and above the sloping profile passing through elevation 500 at the Divine gauge balances the area below the sloping profile line and above the level plane. In other words, the level water-surface profile at elevation 499.2 produces a longitudinal section prism area equivalent to the area outlined by the actual sloping water surface when the reference gauge stands at 500 feet. Then on the gauge height-area curve, water-surface level (fig. 5), the point at elevation 499.2 was projected up to elevation 500, locating a point on the new or corrected curve with the water surface sloping in accordance with the profile. Points at successive 2.5-foot readings of the reference gauge were located in a similar manner and the corrected curve drawn through them.

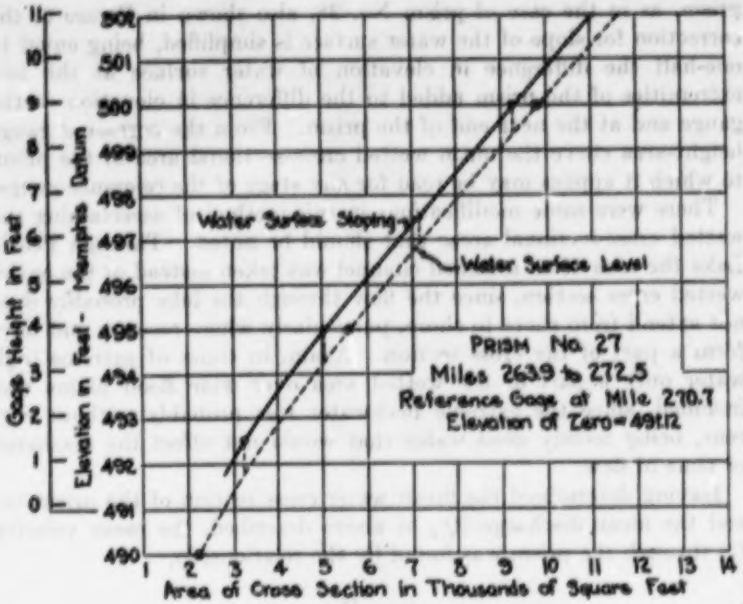


Fig. 5.—Gauge height—area curve of prism No. 27

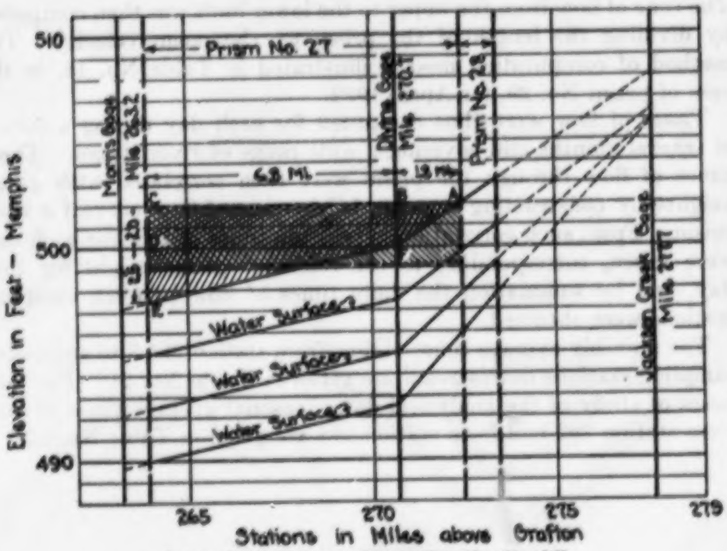


Fig. 6.—Profile of water surface of prisms Nos. 27 and 28

In case the reference gauge was located beyond the limits of the prism, as in the case of prism No. 28, also shown in Figure 6, the correction for slope of the water surface is simplified, being equal to one-half the difference in elevation of water surface at the two extremities of the prism added to the difference in elevation at the gauge and at the near end of the prism. From the corrected gauge height-area curve the mean wetted cross-sectional area of the prism to which it applies may be read for any stage of the reference gauge.

There were some modifications in this method of ascertaining the wetted cross-sectional areas that should be noted. Through Peoria Lake the area of an assumed channel was taken instead of the entire wetted cross section, since the flow through the lake probably does not extend from shore to shore, particularly where recesses and bays form a part of the cross section. Again, in times of extreme high water only a part of the wetted area over wide flood plains was included, since the extreme backwater was probably without current, being merely dead water that would not affect the discharge or time of flow.

Having determined the mean water cross section of the prism (a) and the mean discharge (Q), as above described, the mean velocity (v) through the prism was found by the relationship,

$$v=\frac{Q}{a}.$$

The time of flow from the upper to the lower limit was then computed by dividing the length of the prism by the mean velocity. The method of computation used is illustrated in Table No. 18, in the case of prism No. 29, for April, 1922.

Times of flow were thus computed for each day during a period of several months and covering a wide range of river stages. These times of flow through the prism were then correlated with gauge heights by constructing a gauge height-time-of-flow curve for each prism. From such correlation curves the times of flow for each day were taken, corresponding to the reference gauge height for that day, and by summation the daily times of flow between sampling stations were obtained.

The monthly average times of flow from station 285.8 to successive sampling stations downstream are given in Table No. 21. For purposes of study of the analytical data, seasonal average times of flow from station 292 and from station 148 are given in Table No. 22.

TABLE No. 21.—*Monthly mean time of flow, in hours, from station 285.8 to each sampling station*

Month	Sampling station										
	275	263	247	240	237	234 [1]	196	179	166	163	153
1921											
July	------	11.8	------	30.5	39.5	------	82.9	128	181	195	205
August	------	12.0	------	30.7	39.9	------	88.4	129	181	196	208
September	------	12.4	------	30.4	39.5	------	84.9	134	185	------	208
October	3.46	12.6	------	30.0	39.4	------	85.2	138	186	------	209
November	3.46	12.1	------	27.0	36.1	------	82.2	139	185	------	205
December	3.45	11.5	------	24.6	33.3	------	80.5	138	175	------	195
1922											
January	3.47	12.2	------	27.1	------	38.8	84.0	146	187	------	206
February	3.47	12.5	------	29.3	------	41.8	86.4	148	189	------	210
March	3.45	11.5	------	24.2	------	36.1	81.0	137	177	------	195
April	3.39	10.7	------	20.9	27.4	------	66.8	100	131	------	147
May	3.46	11.9	------	26.0	36.1	------	82.6	140	178	------	195
June	3.46	12.5	24.7	28.7	38.0	------	85.6	142	187	------	206
July	3.45	12.6	25.2	29.4	38.7	------	85.5	132	183	------	207
August	3.46	12.3	25.0	29.3	38.6	------	82.4	128	181	------	206
Maximum	3.47	12.6	------	30.7	39.9	------	88.4	146	189	------	209
Minimum	3.39	10.7	------	20.9	27.4	------	66.8	100	131	------	147
Averages											
July, 1921, to August, 1922, inclusive	3.45	12.0	------	27.2	37.3	------	82.3	134	179	------	200
September, 1921, to August, 1922, inclusive	3.45	12.1	------	27.7	36.9	------	82.2	135	179	------	199
Summer months [4]	3.46	12.3	------	29.5	39.1	------	83.8	132	185	------	206
Winter months [5]	3.46	11.9	------	26.3	37.5	------	83.0	141	182	------	201

Month	Sampling station										
	148	122	101 [2]	89 [2]	84	78	77 [2]	43	33	31	26
1921											
July	211	235	257	268	272	279	280	311	319	320	326
August	211	236	258	269	273	280	282	312	320	321	327
September	213	235	256	266	------	------	276	304	------	312	318
October	213	234	254	264	------	------	274	302	------	310	316
November	211	230	250	260	------	------	270	290	------	290	294
December	197	[3] 213	------	------	------	------	------	265	------	273	277
1922											
January	210	[3] 228	------	------	------	------	------	282	------	290	295
February	214	[3] 233	------	------	------	------	------	293	------	300	305
March	199	[3] 217	------	------	------	------	------	269	------	276	280
April	150	[3] 164	------	------	------	------	------	202	------	207	210
May	200	[3] 216	------	------	------	------	------	266	------	272	276
June	212	[3] 231	------	------	------	------	------	289	------	297	302
July	212	[3] 235	------	------	------	------	------	303	------	311	316
August	210	[3] 237	------	------	------	------	------	313	------	322	326
Maximum	214	237	258	269	------	------	282	313	------	322	326
Minimum	150	164	250	260	------	------	270	202	------	207	210
Averages											
July, 1921, to August, 1922, inclusive	205	225	------	------	------	------	------	285	------	298	297
September, 1921, to August, 1922, inclusive	203	223	------	------	------	------	------	280	------	288	293
Summer months [4]	212	235	257	268	------	------	279	305	------	314	320
Winter months [5]	205	223	------	------	------	------	------	277	------	285	290

[1] Station moved from 236.8 to 234.5 during January, February, and March.
[2] Station discontinued November, 1921.
[3] Time to station 120.9 instead of station 122.5.
[4] Summer months include July, August, and September, 1921, and June, July, and August, 1922.
[5] Winter months include December, 1921, and January, February, and March, 1922.

TABLE No. 22.—*Seasonal average times of flow, in hours, from station 292 to successive sampling stations to station 166, inclusive, and from station 148 to station 26, inclusive*

Time of flow, in hours, from station 292—					Time of flow, in hours, from station 148—				
To station—	Summer season[1]	Winter season[2]	Summer transitional season[3]	Winter transitional season[4]	To station—	Summer season[1]	Winter season[2]	Summer transitional season[3]	Winter transitional season[4]
292	0.0	0.0	0.0	0.0	148	0.0	0.0	0.0	0.0
288	1.3	1.2	1.3	1.3	122	23.0	[5] 17.7	18.4	18.8
286	2.0	2.0	2.0	2.0	101	45.1	---------	40.3	38.9
278	5.5	5.4	5.5	5.4	90	56.0	---------	50.3	48.0
263	14.3	13.9	14.2	13.4	84	62.1	---------	---------	---------
247	27.0	---------	---------	---------	79	65.5	---------	---------	---------
240	31.8	28.3	30.0	25.9	77	67.7	---------	60.6	59.4
227	41.1	30.5	39.2	32.7	43	98.4	72.3	77.0	66.8
196	86.8	85.0	98.0	77.0	32	[6] 109.0	---------	---------	---------
179	134.0	142.0	140.0	122.0	31	102.0	89.1	84.7	67.6
166	156.0	162.0	184.0	160.0	26	108.0	94.5	89.0	71.6

[1] Summer season includes months of July, August, and September, 1921, and June, July, and August, 1922.
[2] Winter season includes December, 1921, and January, February, and March, 1922.
[3] Summer transitional season includes October, 1921, and May, 1922.
[4] Winter transitional season includes November, 1921, and April, 1922.
[5] Time to station 121 instead of to 122.
[6] Average for 2 months only.

The times of flow obtained by this procedure are doubtless subject to considerable error, especially in times of extreme high water, when the flood plains are inundated and storing or discharging water at varying rates. Peoria Lake offers a similar source of error due to the wide expanse of shallow water where no definite forward flow is to be expected continuously. The magnitude of error in estimates for such conditions is not readily ascertainable. However, the greatest variations might be expected to occur at times of abnormal stream conditions, when any accurate estimate of average velocity in a channel of this nature is extremely difficult. Under normal conditions of flow the times of passage to successive sampling stations as calculated are believed to be of a degree of accuracy in general fairly comparable to that of the discharge measurements.

CHAPTER IV

METHODS OF PROCEDURE IN FIELD AND LABORATORY STUDIES

In planning the collection and examination of water samples from the Illinois River and its tributaries, the purpose in view was to measure and record successive changes in the character and intensity of the pollution, resulting either from: (*a*) Additional inflow, whether of polluting wastes or of relatively unpolluted waters from tributaries, or (*b*) changes in the composition of wastes already contained in the stream. The field studies were accordingly planned to assemble sufficient observations of these various factors to portray, as clearly as might be, the actual conditions as they existed.

In order that all the field data collected might be as exactly comparable as possible, it was deemed advisable to adopt uniform methods of procedure in so far as possible and to permit no deviations from these methods during the course of the field work unless absolutely essential and then only on condition that complete records be kept of the details of such changes. The general plan of operating methods as applied to the collection and transportation of samples and to the bacteriological and chemical analyses is discussed below. Certain details of the manner in which specific parts of the study were conducted are necessarily discussed in the presentation of the data to which such methods were applied.

SELECTION OF SAMPLING STATIONS ON THE MAIN STREAM

In locating the sampling stations throughout the river, an effort was made to choose points that were accessible and at the same time significant. In the upper river, where the pollution was greatest and the anticipated changes in chemical and biological content more rapid, the distances between sampling stations were made shorter than in the lower reaches. As far as practicable, sampling stations were located in stretches of river having no marked changes in channel characteristics and at points that were not affected by disturbing influences such as large sewer outlets and confluence of tributaries. Sampling stations were located just above the mouths of the larger tributaries and at sufficiently great distances below their outlets to permit of fairly thorough mixing of the confluent waters. Stations were also located both above and below the Illinois River dams at Marseilles, La Grange, and Kampsville; because of the swift current, samples were never actually collected from the station below Marseilles Dam; and the variations between the samples taken above and below the other dams were so slight that collection at the upper stations was discontinued August 13, 1921.

As before noted, each sampling station on the main stream was designated by a number corresponding to the number of miles, by river, of the point above Grafton, Ill. Mileage to the stations was taken from the map (scale 1 inch equals 600 feet) made by the Corps of United States Army Engineers from their survey of 1904. Table No. 23 shows the location of sampling stations selected for the investigation, with their corresponding numbers (miles above Grafton, Ill.) together with information relative to the entrance of tributaries above or below the station, character of river channel, condition of banks, etc.

TABLE No. 23.—*Location of sampling stations along main river channel, together with physical features of the stream above and below sampling points*

Sampling station	River station	City or town	Location	Tributaries entering	Condition of flow, channel, and banks
292	292.0	Lockport	Chicago Drainage Canal, Sixteenth Street Bridge.		Flow sluggish to station 291.0.
	291.0	do	Dam and power house end of sanitary canal.		Water dropped 35 feet over bear-trap dam and through turbines.
	288.8	Joliet		Confluence Canal and Des Plaines River.	Flow sluggish to station 288.5.
288	288.7	do	Ruby Street		
	288.4	do	Dam and power house		Water dropped 10 feet.
	288.1	do	Cass Street		Flow swift and turbulent through rock channel. Quantity variable, depending on regulation of control gates at power houses.
	287.9	do	Jefferson Street		
	287.3	do	McDonough Street		
286	285.8	do	Brandon Road		
	280.8				Channel widens, current slower between stations 285.8 and 280.8.
	279.0				Channel narrows, current swift but not particularly turbulent down to station 273.0.
278	277.6	Channahon	Smith's bridge		
	277.3				
	273.0			Dupage River	
263	263.2	Morris	Highway bridge	Kankakee River	Sharp band in channel of main river followed by straight flow to station 263.2. Current swift but smooth. Evidence that water of Illinois and Kankakee are not thoroughly mixed. Between stations 263.2 and 247.3, section regular, channel straight, current moderate and smooth; at 247.3 water slightly pooled by dam below, but an appreciable current even at low stages; below 247.3 two head races take off for power at three industrial plants.
247	247.3	Marseilles	Above dam		
	247.0		Marseilles Dam		Overflow crest extends entire width of river (about 1,000 feet); fall approximately 10 feet; always flows over dam.
	245.7				Tailrace from mills enters river.
	244.0				Between stations 247.0 and 244.0 current swift and turbulent due to steep slope and rock floor of channel.
240	239.9	Ottawa	0.2 mile above mouth of Fox River sewer outlets at Ottawa.		Current swift but smooth. For 15 miles below station 239.9 channel tortuous, with many islands.
	239.7	do		Fox River	
	230.9	Utica	Starved Rock		North bank bordered by flood plain ½ mile or more in width.
227	226.8	La Salle			Channel crooks sharply above and below this station. Flood plain on north, ¼ mile wide; south, 1 mile.
	226.5	do			
	223.2	Peru		Vermilion River	Below La Salle flood plain ranges from 1½ to 3 miles in width.
	211.0				Terminus Illinois & Michigan Canal.
	210.3				Change in course from due west to nearly south.
	199.0				Illinois & Mississippi Canal takes off. Flow into Illinois negligible.
	196.1	Henry	Henry lock and dam		Senachwine Lake and Mud Lake outlet into river.
196	196.0	do	Henry wagon bridge		Between 196.0 and 179.0 current sluggish and channel is flanked on one side or the other by sloughs and backwater.
179	179.0		Above head of Peoria Lake		From stations 179.0 to 166.1 flow through upper Peoria Lake current is practically imperceptible.
	167.1		Head of "Narrows"	Ten-Mile Creek	Following rains, discharge from creek turbid; believed high turbidity at 166.1-E due to Ten-Mile Creek.

TABLE No. 23.—*Location of sampling stations along main river channel, together with physical features of the stream above and below sampling points*—Continued

Sampling station	River station	City or town	Location	Tributaries entering	Condition of flow, channel, and banks
166	166.1	Peoria	Under free bridge at Narrows between upper and lower Peoria Lakes.		Peoria Lake is widening of river channel of from 1 to 2 miles. Maximum depth below low water, 1921, approximately 20 feet; normal depth in channel, 10 to 16 feet. North shore in general bordered by sandy beach and high ground with summer cottages. South shore flanked intermittently by sharply rising slopes, on which are scattered groups of farm buildings and low flat areas covered with sloughs and backwater.
162	162.3	do.	Lower wagon bridge, lower end of lake.		From outlet of Peoria Lake to the mouth at Grafton the channel is quite regular and current uniform. Flood plain varies from 3 to 5 miles in width and generally slopes toward bluffs. Both banks of river, with the exception of the lower 40 miles, are bordered by low ground, much of which has been drained and is under cultivation. Many undrained backwater areas, lakes, and bays still remain, which may affect to some extent the condition of the river water.
153	153.5	Pekin	Above outlet of Pekin Lake		Shows effect of pollution contributed by Peoria, large amounts of which enter the river.
	153.0	do.	Opposite city		Domestic and industrial sewage of Pekin enter river between stations 153.0 and 151.0
	150.0	do.	Below city		Sharp bends in river channel at stations 151.0 and 150.0.
148	147.9		Below Turkey Island above Mackinaw River.		Analyses show that wastes from Pekin are not uniformly distributed over river section in spite of bends.
	147.7			Mackinaw River	Between stations 147.9 and 122.5 the river bottom lands contain many sloughs and lakes which are connected with the river at their lower extremities. Some of the bottom land has been leveed and drained by pumping.
122	122.5		Above mouth Quiver and Thompson Lakes.		
121	120.9				
	120.6			Spoon River	
	119.9	Havana	Havana highway bridge		
101	100.8		½ mile above Hickory Island		
	98.0			Sangamon River	
89	88.6	Beardstown	Beardstown highway bridge		
84	84.0		Above mouth of Crooked Creek		
	82.8			Crooked Creek	
78	78.0	La Grange	0.4 mile above La Grange Dam		
	77.6		La Grange Dam		
77	76.7		Below dam		
43	42.9	Pearl	Below Chicago & Alton R. R. bridge		From this station to mouth, west bank is bordered by sharply rising ground and limestone cliff. A low flood plain borders on the east bank, but is almost entirely inclosed by levees and drained.
32	31.8	Kampsville	Above Government lock and dam		
	31.5	do.	Government lock and dam		
31	30.9	do.	Just above Willow Island		
26	25.7		Between Diamond and Hurricane Islands.		
	23.0			Macoupin Creek	
	0.0	Grafton	Weather Bureau gauge north of river		

At the river sections selected, two classes of sampling stations were established: (*a*) At all places above mile 263.2, and on all tributaries, single-point stations from which one sample was collected from the center of the stream at mid-depth, and (*b*) three-point stations at which samples were collected at mid-depth as for single-point stations but at the center of each third of the cross-sectional area.

The locations of the points in the three-point sections were determined from a cross section of the channel taken from the map and verified by sounding. Soundings were plotted and the wetted cross-sectional area divided transversely into three equal parts. The central point of each third of the cross-sectional area was located in the stream and referred to landmarks by which it could be readily relocated by the person making the routine sample collection. In each instance a sketch of the landmarks was made, a copy of which was supplied to the sample collector to assist him in locating the sampling point. Points were designated as east (E), center (C), and west (W), the east point being on the left-hand side of the river, and the west on the right, regardless of the direction in which the river was flowing at the sampling station. Cross sections were made while the river was at medium stage. No corrections were made for the lateral shifting of the centers due to changes of river stage. For the purpose of illustration, the cross section at sampling station No. 240 is shown in Figure 7 and a sketch of the selected landmarks in Figure 8.

SAMPLING STATIONS ON PRINCIPAL TRIBUTARIES

In order to determine the extent of pollution or dilution being introduced by tributary streams, samples were collected regularly from each of the principal ones. Sampling stations were definitely located in each case at some accessible place near the mouth and were of the single-point type, the sample being taken at the approximate center of the stream and at mid-depth. The stations at which the various tributaries enter the Illinois River are shown in Table No. 23. The location of their sampling stations and other pertinent information may be briefly stated.

The Des Plaines River above the junction with the Chicago Sanitary Canal was first sampled at Sixteenth Street Bridge at Lockport and later at Lemont.

Except during times of high water, practically the entire flow of the Kankakee River is diverted through a high-level canal for water-power development. The sample of Kankakee River water was collected from this canal at Wilmington.

The Fox River sample was collected from the Chicago, Rock Island & Pacific Railroad bridge at Ottawa. This station is above the Ottawa sewer outlets and approximately 1¼ miles upstream from the junction with the Illinois River.

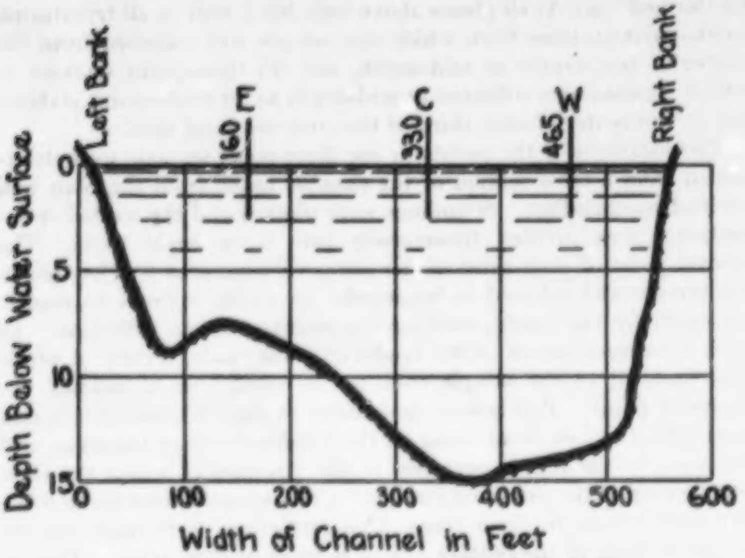


FIG. 7.—Cross section of the Illinois River at station 240, May 13, 1921

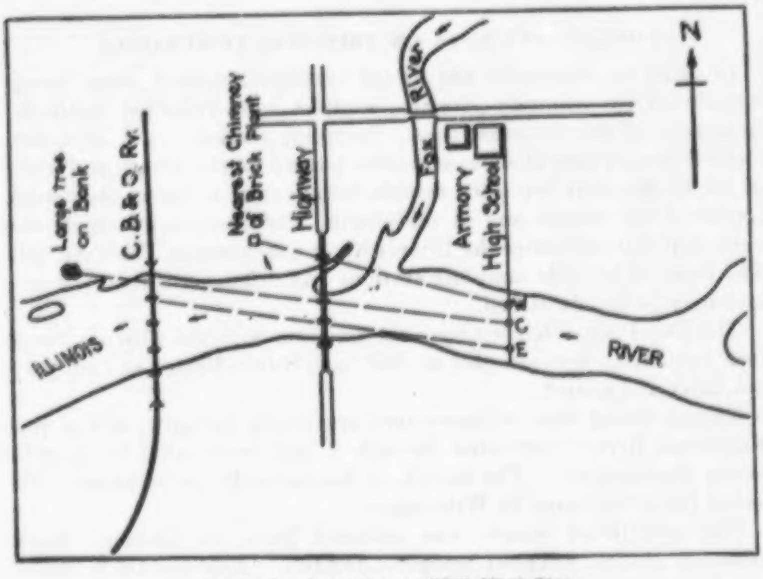

N
Fox River
Nearest Chimney of Brick Plant
Highway
Armory
High School
Large tree on Bank
C.B.&Q. Ry.
W
C
E
ILLINOIS
RIVER

FIG. 8.—Sampling section at mile 240, Illinois River

The sample from the Vermilion River was taken at a point about one-fourth mile above the mouth of the stream. During a portion of the winter the river was frozen over and the sample was collected through the ice about a half mile above the mouth.

The Mackinaw River formerly discharged to the Illinois through two outlets, the larger at mile 151 and the smaller at 147.7. By the construction of a levee, the major outlet has been intercepted and practically the entire flow during the period of the investigation was discharged from what was formerly the smaller outlet. The sample was collected, except during a part of the winter when the river was frozen, at a point about one-fourth mile from the mouth of the stream.

The Spoon River enters the Illinois River opposite the city of Havana. Samples were collected about one-half mile above the mouth. For a distance of 4 or 5 miles above its mouth the Spoon River flows over a low flood plain of the Illinois River. During the high water of April, 1922, the flood plain was entirely submerged and the water of the Spoon River at the sampling station was so diluted with Illinois River water that sampling was discontinued for the period April 19 to May 10, 1922. With the exception of this period and for a few days during winter, samples were collected at this station daily.

The channel of the Sangamon River divides on reaching the Illinois flood plain and enters through several outlets. Samples for analysis were collected from the mouth at station 99, opposite the lower end of Hickory Island, about one-fourth mile upstream from the Illinois River. At times of medium stage and high water, the sample probably consisted of a mixture of Sangamon River water and water from Turner Slough and other backwater. It is probable that at such times some Illinois River water was contained in the sample also.

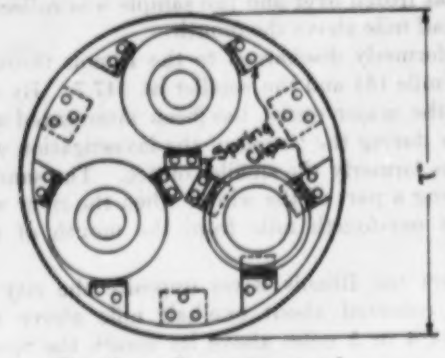
The Crooked Creek sample was collected about one-half mile upstream from the Illinois River. Samples from this point were probably representative of Crooked Creek water at all times during the period samples were collected.

Macoupin Creek discharges through a dredged channel entering the Illinois River above the lower end of Diamond Island. Samples were collected at a point approximately 1 mile upstream from the mouth. The samples were probably never affected by Illinois River water or slough water. The channel of the creek at the sampling station is straight and confined between high banks.

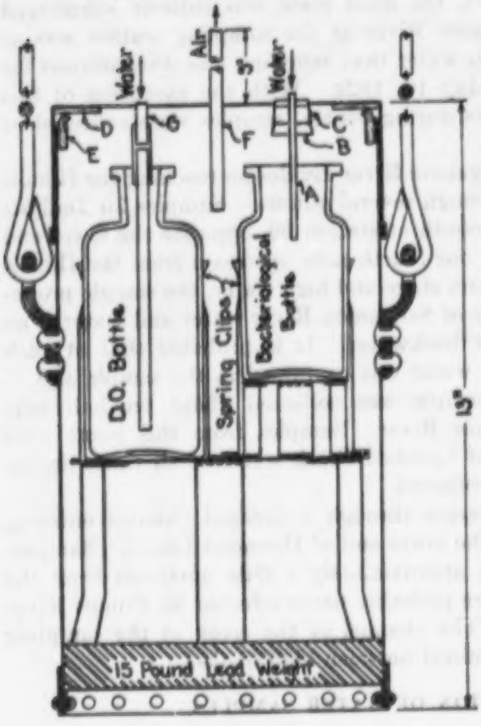
COLLECTION OF WATER SAMPLES

Samples for biological, bacteriological, and chemical analyses were collected from the selected stations throughout the 291 miles of river extending from the outlet of the Chicago Main Drainage Canal above

Joliet to a point near the mouth at Grafton. Samples were also collected from all important tributaries, and in addition the Sanitary District of Chicago analyzed samples collected from Lake Michigan and from the main drainage canal at Summit, Ill.



Top View, Cover removed.



Sectional View

FIG. 9.—Sample collector of galvanized iron

All regular samples for bacteriological and chemical analyses were collected with either of two types of sample collectors, one constructed of copper, the other of galvanized iron. The copper collectors were those previously used in the Ohio River investigation, while the galvanized-iron collectors, illustrated in Figure 9, were designed for the Illinois River studies, modeled from the type previously used by the Sanitary District of Chicago. The galvanized collector was composed of the same essential parts as the copper collector, the principal difference being that the body and cover were made of heavy-gauge galvanized iron instead of copper and that the cover was held in place by a close-fitting slip joint instead of being bolted.

The type of sampling device used permitted the filling, simultaneously, of three sample bottles with water from the sampling point. Two of these specimens were used for the oxygen deter-

minations and the other for bacteriological analysis. Where an additional quantity of the sample was required for compositing for mineral analysis, this was obtained by filling an extra bottle from the contents of the collecting chamber.

The bacteriological bottles, which were of about 150 c. c. capacity, were provided with a tin-foil cover over the stopper, were wrapped in paper, and autoclaved at the laboratory before being sent to the sampling station. In removing the paper and stopper and placing the bottle in the collector, care was taken to avoid contaminating the stopper or the neck of the bottle. The water was admitted to the bacteriological bottle through a sterile glass tube previously placed in the lid of the collecting device and held in position by a rubber stopper fitted into the copper ferrule in the cover. The glass tubes were wrapped in paper and autoclaved at the laboratory before being used. In passing the glass tube through the stopper, the tube itself was not touched. The paper was carefully removed from one end of the tube, which was passed through the stopper, and the paper then removed from the end by which the top was held. A fresh tube was used for each sample collected.

In taking the samples the bottles were placed in the collector and lowered to mid-depth of the stream. When bubbles of air ceased to rise to the surface the can was full and raised from the river. The bottles were removed from the collector and carefully stoppered, care being taken that no air bubble was left within the oxygen sample bottles. An air space of about 1 inch was purposely left in the bacteriological bottle. This bottle was rewrapped in the paper in which it came, to prevent contamination while being returned to the laboratory. The temperature of the water remaining in the can after the bottles were removed was taken and recorded as the temperature of the sample at the time of collection.

In general the galvanized-iron sample collector worked very satisfactorily. Some trouble was experienced in cold weather when the temperature of the river water was at the freezing point, due to the tubes of the collector frequently freezing shut as soon as water touched them. Warming the tubes before dropping the collector into the water remedied this trouble quite effectively.

In Table No. 24 are shown the sampling schedules for stations on the Illinois River and tributaries, together with the means used to reach the sampling points on the river.

TABLE No. 24.—*Data relative to the collection and transportation of samples*

Sampling point	Samples collected	Samples analyzed at—	Method of transportation	Time in hours between collection and analysis	Iced in summer	How collected
293.0	Daily	Joliet	Automobile	2.9	No	Bridge.
288.7	do	do	do	2.8	No	Do.
286.1	do	do	do	2.6	No	Do.
287.0	do	do	do	2.7	No	Do.
287.2	do	do	do	2.7	No	Do.
285.8	do	do	do	2.4	No	Do.
277.6	do	do	do	3.1	No	Do.
263.2	do	do	Express	6.6	Yes	Do.
247.2	do	do	do	8.2	Yes	Boat.
230.9	do	Peoria	do	7.0	Yes	Do.
226.8	do	do	do	7.2	Yes	Do.
195.0	do	do	do	6.6	Yes	Bridge.
179.0	do	do	Automobile and trolley	3.3	Yes	Boat.
166.1	do	do	do	1.7	No	Bridge.
162.2	do	do	do	4.0	No	Do.
158.5	do	do	Motor boat and trolley	2.2	Yes	Boat.
147.9	do	do	do	3.1	Yes	Do.
122.5	do	do	Express	7.2	Yes	Do.
120.9	do	do	do	7.2	Yes	Do.
100.8	Triweekly	Beardstown	Motor boat	4.9	No	Do.
98.6	Daily	do	do	2.2	No	Bridge.
84.0	Triweekly	do	do	5.0	No	Boat.
78.0	do	do	do	6.0	No	Do.
76.7	do	do	do	4.4	No	Do.
42.9	do	Kampsville	do	4.7	Yes	Do.
31.8	Daily	do	do	2.7	Yes	Do.
30.9	do	do	do	3.2	Yes	Do.
25.7	Triweekly	do	do	4.8	Yes	Do.
Des Plaines	Daily	Joliet	Automobile	2.1	No	Bridge.
Kankakee	do	do	Express	4.5	Yes	Do.
Fox	do	Peoria	do	7.1	Yes	Do.
Vermilion	do	do	do	7.0	Yes	Boat.
Mackinaw	do	do	Motor boat and trolley	3.2	Yes	Do.
Spoon	do	do	Express	6.3	Yes	Do.
Sangamon	Triweekly	Beardstown	Motor boat	2.7	No	Do.
Crooked Creek	do	do	do	3.1	No	Do.
Macoupin Creek	do	Kampsville	do	5.1	Yes	Do.

Immediately upon the collection of each sample, the following information was noted on tags attached to the two oxygen sample bottles and written upon the wrapper of the bacteriological sample bottle:

Date.
Time of day.
Sampling station number.
Point (E, C, or W).
Temperature of water.
Name or initials of attendant collecting the sample.

DELIVERY OF SAMPLES

In Table No. 24 is given data relative to the laboratories to which the various samples were sent for analysis, the method of transportation, time between collection and examination, etc.

For forwarding samples of water by railway express a shipping case of the type illustrated in figure 10 was utilized. The case consists of a wooden box with hinged cover lined with galvanized iron, inside of which a galvanized-iron bottle container is supported on a wooden stand and held in place by springs attached to the sides of the box. Sample bottles are supported inside the container by a perforated galvanized-iron disk with space for 12 sample bottles.

When packing for shipment, the bottles containing the water samples were placed in the inside container and packed with excelsior. During warm weather the space below and around the sides of the container was packed with ice. By special arrangement with the American Railway Express Co., immediate delivery at the laboratory was secured as soon as the samples arrived at the railroad station.

CHEMICAL METHODS

The routine chemical analyses performed on each sample as received at the field laboratories consisted of determinations of turbidity, alkalinity, immediate dissolved oxygen, and five-day oxygen demand at 20° C.

Ten-day composite samples preserved with sulphuric acid were made from the daily samples of selected sections, and these composites forwarded to the Cincinnati laboratory for sanitary chemical analysis, where determinations were made of the nitrogen as free ammonia, Kjeldahl nitrogen, nitrogen oxides, and oxygen consumed.

TURBIDITY

The standard candle turbidimeter was used to determine turbidities of 25 parts per million or over, the vanishing point being taken as that depth of sample at which the image of the standard candle flame first becomes evenly diffused over the entire cross section of the turbidimeter tube. Where turbidities of less than 25 parts per million were to be determined, bottle standards of standard silica suspension were used.

ALKALINITY

The alkalinity was determined on a composite of the three samples received from a sampling station or on the individual sample where only one such sample was collected, methyl orange being used as the indicator.

DISSOLVED OXYGEN

The initial dissolved oxygen content was determined on all samples as soon as received at the laboratory. To insure uniformity of results, all reagents used were prepared at the headquarters station. The N/40 thiosulphate solution was standardized against a standard N/40 potassium biniodate solution. Sulphuric acid was used for acidification instead of hydrochloric acid as prescribed in Standard Methods, 1920.

To eliminate the interference of nitrites, the permanganate modification of the Winkler method of dissolved oxygen determination was adopted as a routine procedure. Seven-tenths of 1 c. c. of concentrated sulphuric acid was first added to the 350 c. c. sample and then 1 c. c. or less of a fifth normal solution of potassium permanganate. The mixture was shaken thoroughly and allowed to stand for 20 minutes, more permanganate being added in 0.5 c. c. amounts if necessary. A suitable quantity of a 2 per cent solution of potassium oxalate was then added and thoroughly mixed, which would ordinarily discharge the color by the end of four minutes, unless the sample was very cold, in which case more time was allowed. After the disappearance of the permanganate colo:, 1 c. c. of manganous sulphate and 3 c. c. of alkaline iodide were added in the order given, all of the reagents being applied below the surface of the sample. After mixture and sedimentation had taken place the precipitate was dissolved with 2 c. c. of concentrated sulphuric acid. An amount

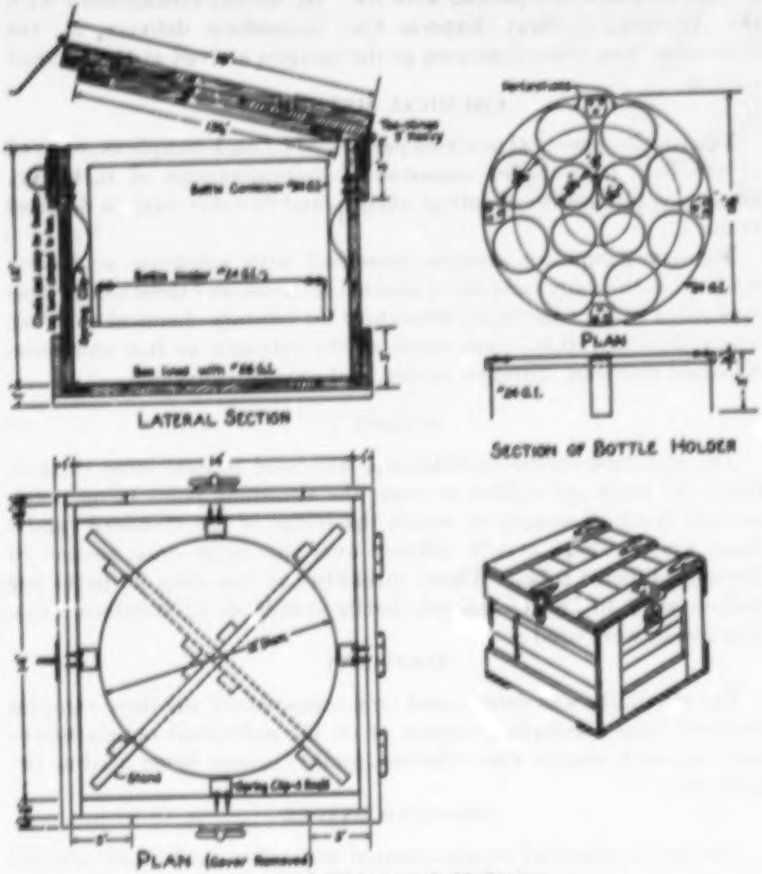

Bottle Container #24 G.I.
Bottle Holder #24 G.I.
Box lined with #26 G.I.
LATERAL SECTION
Perforations
#24 G.I.
PLAN
#24 G.I.
SECTION OF BOTTLE HOLDER
14"
Stand
Spring Clip & Bolt
PLAN (Cover Removed)

FIG. 10.—Laboratory sample shipping case

of the resulting solution corresponding to 200 c. c. of the original sample was then titrated with N/40 sodium thiosulphate solution in the usual manner. The dissolved oxygen in parts per million was then equivalent to the number of cubic centimeters of N/40 sodium thiosulphate solution used.

OXYGEN DEMAND

The difference between the amount of dissolved oxygen originally present in the sample and the amount present after five days of incubation at 20° C. was taken as a measure of its five-day oxygen demand. In order to reduce the amount of routine work, composites were prepared of samples originating from stations where three individual samples were collected. The initial dissolved oxygen was determined on this composite in all cases to obtain the dissolved oxygen content at the start of the incubation period. Due to the high organic content of the Illinois River water, dilution of most of the samples was necessary to prevent undue depletion of the oxygen supply during the incubation period. The detailed procedure of the oxygen demand determination has been discussed in previous publications[1] and need not be repeated here, except to note some variations in procedure made necessary by local conditions.

During periods of cold weather, and from other causes, certain samples were frequently received supersaturated with oxygen. Such samples were gently warmed and shaken until the oxygen content was reduced to 10 parts per million or less, after which the oxygen content was determined before incubation was started. Conversely, certain samples were at times encountered in which the dissolved oxygen content was practically exhausted and the oxygen demand almost satisfied. Dilution of such samples would result in inappreciable depletions of oxygen, while sufficient oxygen was not present in the initial sample to satisfy the depletion to be expected during the five-day incubation period. This condition was remedied by placing such samples in 2-liter bottles and shaking them vigorously for 20 to 30 seconds, at the end of which time and after entrained air had been expelled the oxygen content would be increased to between 8 and 9 parts per million.

SUSPENDED MATTER

Determinations were made of suspended matter contained in samples collected from selected stations in accordance with the procedure described in Standard Methods. The usual amount filtered for this determination was 500 c. c.

---

[1] (a) Sewage Disposal in the United States. Wagenhals, Theriault, and Hommon. Public Health Bulletin No. 132, Washington, D. C.

(b) The Determination of the Biochemical Oxygen Demand of Industrial Wastes and Sewage. Theriault and Hommon. Public Health Reprint No. [illegible], Washington, D. C.

(c) The Determination of Dissolved Oxygen by the Winkler Method. E. J. Theriault. Public Health Bulletin No. 151, Washington, D. C.

METHODS OF ANALYSIS OF SANITARY CHEMICAL SAMPLES

Samples for sanitary chemical analysis were regularly collected, as described above, from stations 292, 286, 263, 240, 227, 196, 179, 166, 148, 101, 77, 43, and 26 of the main stream, and from the mouths of all the important tributaries. When the samples had reached the laboratory, the procedure was to composite suitable amounts over 10-day periods of time, the intervals being so chosen that the first composite extended from the 1st to the 10th of any given month, while the second composite comprised the period from the 11th to the 20th, and the third covered the remainder of the month. The number of subsamples included in a 10-day composite depended on the number of such samples collected during the 10-day period. In all cases, the volume of individual sample was such that the total composite secured for analysis amounted to approximately 2 liters. At the end of each 10-day period the composite samples were forwarded to the Cincinnati laboratory for analysis.

The three monthly composite samples were analyzed separately, and the results obtained were combined to give the average composition of the water for a given month. Determinations were made on each composite of the free ammonia, Kjeldahl nitrogen, nitrogen oxides by the reduction method, and oxygen consumed. The organic nitrogen may be obtained by subtracting the nitrogen as free ammonia from the Kjeldahl nitrogen, while the total nitrogen is equivalent to the sum of Kjeldahl nitrogen and nitrogen oxides including both nitrates and nitrites. Standard methods [9] were closely followed, except that, in the determination of nitrogen oxides, the free ammonia was not boiled off but the value of this constituent, independently determined by direct nesslerization, was deducted from the total value obtained.

The composite samples were preserved by using 1,000 parts per million of sulphuric acid, all of which was added at the time the composite was started. The efficacy of sulphuric acid as a preservative was fully established by an extensive series of tests. A discussion of this procedure is contained in Appendix B.

BACTERIOLOGICAL METHODS

For the purpose of standardizing laboratory methods, the technicians engaged at all the laboratories were given an intensive course of training at the central laboratory at Peoria before being assigned for regular duty. Furthermore, the routine methods employed by the technicians were frequently checked during the course of the field study by visits of the bacteriologist to the various laboratories located along the river. In this way slight variations from the routine procedure could be immediately eliminated.

---

[9] Standard Methods for the Examination of Water and Sewage, fourth edition, 1920. American Public Health Association, New York.

The routine samples were examined bacteriologically immediately upon their receipt at the laboratories, this examination consisting in the determination of the number of colonies per cubic centimeter of the sample developing on agar in 24 hours at 37° C. and on gelatin in 48 hours at 20° C., and an estimation of the numbers of *B. coli* present. The standard procedure as outlined by the American Public Health Association was followed in this work with few exceptions.

In order to reduce the routine bacteriological work within limits that could be handled by the available personnel, the individual samples from the three points on each of the various cross sections were composited for the bacteriological examination. The composite was made by withdrawing, by means of sterile pipettes, 10 c. c. of water from each of the three bacteriological samples as received and placing these portions in a sterile bacteriological bottle. The inoculation of plates and broth tubes was then made from this composite in the usual manner. Before adopting the compositing method, an extensive series of tests was carried out to ascertain the extent of error to be expected by such procedure. Moreover, throughout the progress of the field work each laboratory made daily bacteriological analyses of the three individual points on at least one section as well as of the composite of the same section. These results entirely justified the procedure, and, moreover, provided a continuous check on the bacteriological technique employed at the various laboratories.

CULTURE MEDIA

All culture media were prepared at the stream pollution laboratory at Cincinnati and forwarded to the various field laboratories as needed, on weekly requisitions. For the routine work, five kinds of media were required: Nutrient gelatin, nutrient agar, 3 per cent agar base for Endo's medium, sugar-free double strength broth for lactose broth, and Clark's dextrose-peptone-phosphate medium. Standard methods were followed in preparing these media, with the following exceptions:

Nutrient gelatin was prepared by using 12.5 per cent of undried gelatin and 1 per cent of peptone. The reaction of the medium was so adjusted that after the final sterilization it had a hydrogen ion concentration between pH 6.4 and pH 7.4, the usual range being between pH 6.8 and pH 7.0. The medium was finally bottled in flat flasks of 200 to 225 c. c. capacity, and sterilized at 15 pounds steam pressure for 15 minutes after the pressure had reached 15 pounds.

Nutrient agar was prepared with 1.5 per cent of undried agar and with 1 per cent of peptone. The bottling, sterilization, and adjustment of reaction was in all respects similar to the procedure adopted for nutrient gelatin.

Nutrient broth from which lactose broth was to be made was prepared in double strength for convenience in shipping. It contained in its final dilution, 1 per cent of peptone, and its final reaction was adjusted to the same point as that adopted for the gelatin and agar. The double strength broth was put up in 2-liter, ground-glass stoppered bottles. Sterilization was effected by placing the filled bottles in streaming live steam for 20 minutes previous to submitting them for 15 minutes to a steam pressure of 15 pounds. Lactose broth was prepared by adding to a given volume of this double strength, sugar-free broth an equal volume of sterile 2 per cent lactose solution in distilled water, immediately before it was put up in Durham tubes. In order to avoid breaking down of the lactose into other sugars, extreme precautions were observed to avoid contamination and the consequent necessity of applying excessive or prolonged heat to this sugar. The 2 per cent lactose solution was sterilized by holding in streaming steam at 100° C. for 1.5 hours immediately before it was added to the broth. The mixture was placed in sterile Durham tubes under aseptic conditions, and the filled tubes then heated for one-half hour in streaming steam after the temperature had reached 100° C. Each set of broth tubes prepared in this manner was placed in the 37° incubator and tested for sterility before being used in routine work.

Endo agar base was prepared by using 1 per cent of peptone, 0.5 per cent meat extract, and 3 per cent of agar by net weight. The most satisfactory results were obtained when the hydrogen ion concentration was so adjusted as to give a reading of pH 7.8 after the final sterilization. The original method as prescribed by Endo[3] for the addition of fuchsin and sulphite to the Endo agar base was strictly followed, since from a long series of tests this method seems most favorable and efficient for isolation of all members of the *B. coli* group. To each 400 c. c. of the thoroughly melted agar was added 20 c. c. of a sterile 20 per cent solution of C. P. lactose in distilled water, 2 c. c. of a saturated (10 per cent) solution of basic fuchsin in 95 per cent alcohol, and 0.5 gram of sodium sulphite C. P. (anhydrous) dissolved in 10 c. c. of sterile distilled water. Immediately following the addition of the sulphite, the agar was thoroughly shaken to insure a complete mixture of the chemicals, care being taken to prevent the entrainment of air bubbles. The plates were then poured and allowed to harden in the usual manner. This procedure gives a distinctly red-tinted medium while hot, which on cooling becomes almost colorless.

Dextrose-peptone-phosphate broth (Clark's) was prepared in strict accordance with Standard Methods, 1920, except that as the medium was shipped in bottles to the various laboratories, an additional sterilization of 30 minutes at 100° C. was necessary when the medium was tubed for use. Tests made at the Peoria laboratory using a variety of cultures from strains of known fecal and grain origin and which had been previously checked with various media, indicated that in no case did the extra sterilization vitiate the diagnostic value of the medium. Kahlbaum's phosphate and dextrose and Difco peptone were used throughout in preparing the medium.

---

[3] Endo, S. Über ein Verfahren zum Nachweis der Typhus Bacillen.—Centralblatt. F. Bakt. Part I, vol. 35, p. 109 (1903-4).

Sterility controls were made of each lot of medium as soon as its preparation was completed. Furthermore, daily controls were run of each bottle of medium used, as well as of each lot of dilution water, the dilution water being added with pipettes taken from pipette cans used on that day. By this procedure, it was possible to detect any contamination either of media or of apparatus. In only two or three instances were contaminations encountered, all of which were with gelatin. The results obtained from such contaminated media were discarded.

APPARATUS

Eight-ounce, wide-mouthed, ground-glass stoppered bottles were used throughout as containers for the bacteriological samples. The bottle neck and stopper were covered with a sheet of tin foil and the closed bottle then wrapped securely in heavy brown paper. Sterilization was accomplished by baking in the hot-air oven for two hours after the temperature had reached 165° C.

Sterile pipettes of 1, 2, and 10 c. c. capacity were used, the latter for measuring 10 c. c. of liquid only, the 1 and 2 c. c. pipettes being used for measuring 1 c. c. and 0.1 c. c. portions, except that whenever the 0.1 c. c. portions were being delivered for duplicate plates the 1 c. c. pipette was always used. Petri dishes with glass tops 100 mm. in diameter were used for practically all of the bacteriological work. For some samples, where considerable trouble was experienced with spreaders, porous earthenware tops were used.

Tap water was first used for dilution water, but due to the incrustants contained, was later discarded and distilled water substituted. Sterilized river water was finally employed at all the laboratories. Dilution water was prepared in bottles of approximately 125 c. c. capacity, each containing 99 c. c. of water after sterilization. The loss of volume of water in the dilution bottles during sterilization varied with the individual sterilizer in use, and was experimentally determined at each laboratory for the particular sterilizer employed.

DETERMINATION OF TOTAL COUNTS

The methods employed for making the total counts on gelatin and on agar media were practically those recommended in Standard Methods, 1920 edition.

In plating the sample, either 1 c. c. or 0.1 c. c. of water was always used and was delivered directly to the plates from calibrated pipettes of 1 c. c. and 2 c. c. capacity. Amounts of sample smaller than 0.1 c. c. were obtained by dilution. These dilutions were prepared by adding 1 c. c. of the sample to 99 c. c. of dilution water. Further dilution, where required, was made by adding 1 c. c. from the first dilution bottle to a second dilution bottle containing 99 c. c. of sterile water. One cubic centimeter and one-tenth cubic centimeter of the mixture in the first dilution therefore represented 0.01 c. c. and 0.001 c. c., respectively, of the original sample, while like amounts of the second dilution represented 0.0001 c. c. and 0.00001 c. c., respectively, of the undiluted sample.

Three gelatin and three agar plates were made from each sample, two out of three in each set being planted with the same amount. For these duplicate plates, an amount was used that would ordinarily give not less than 25 (unless the total count from 1 c. c. of the undiluted sample was less than 25) or more than 400, preferably not more than 200, colonies per plate. The third plate in each set was inoculated with either one-tenth or 10 times the amount used for the duplicate plates, depending upon whether it was more probable that too many or too few colonies, respectively, would develop on the duplicate plates.

Agar plates were incubated for 24 hours at 37° C., and gelatin plates 48 hours at 20° C. before counting. Glass-topped plates were inverted in the 37° C. incubator, but clay-topped ones where used, were placed upright. In making the counts, a standard reading lens was employed at all laboratories. Notation on the record was made of spreader colonies in agar plates and of interfering liquefying colonies on gelatin plates.

Definite rules were adopted for the determination of numbers of bacteria per cubic centimeter in the original sample as indicated by the counted plates as follows:

(1) When the duplicate plates in a series of three gave more than 25 and less than 400 colonies per plate, and the third plate less than 25 or more than 400 colonies, the third plate was omitted from the average, unless it fell between the other two, in which case it was included. Examples:

(*a*)	0.01 c. c.	92	
	0.01 c. c.	76	
	0.001 c. c.	6	(Omit; too few.)
	Result	8, 400	bacteria per cubic centimeter.
(*b*)	0.1 c. c.	857	(Omit; too many.)
	0.01 c. c.	127	
	0.01 c. c.	156	
	Result	14, 200	bacteria per cubic centimeter.
(*c*)	0.01 c. c.	92	
	0.01 c. c.	76	
	0.001 c. c.	9	(Include; intermediate between duplicate plates.)
	Result	8, 600	bacteria per cubic centimeter.

(2) Where the duplicates both showed too many or too few colonies, only the third plate was considered in the average result. Examples:

(*a*) 0.01 c. c.	847	(Omit; too many.)
0.01 c. c.	732	(Omit; too many.)
0.001 c. c.	95	
Result	95, 000	bacteria per cubic centimeter.
(*b*) 0.1 c. c.	65	
0.01 c. c.	8	(Omit; too few.)
0.01 c. c.	7	(Omit; too few.)
Result	650	bacteria per cubic centimeter.

(3) Where one of the duplicate plates gave an obviously erroneous count, it was disregarded in recording the average result. Example:

0.1 c. c.	68	
0.1 c. c.	29	(Spreaders; omit.)
0.01 c. c.	10	(Omit; too few.)
Result	680	bacteria per cubic centimeter.

DETERMINATION OF B. COLI

In the routine procedure of *B. coli* determination, the partially confirmed test was used, except that on one day of each week one sample from each sampling point was carried through the complete confirmation as outlined below. It was assumed, from previous experience, that the partially confirmed cultures, if fully identified, would almost invariably prove to be organisms of the *B. coli* group. To establish the correctness of this assumption, the weekly complete confirmations were performed. Of this series, consisting of 3,022 determinations, 92.54 per cent of the partially confirmed colonies, when completely identified, proved to be of the *B. coli* group.

a. Presumptive and partially confirmed test.—Three graduated decimal portions of each sample to be examined were planted, the amounts being so selected that the largest would show gas formation and the smallest give a negative result. Lactose broth medium in Durham tubes was used exclusively, and in amounts at least three times the volume of water planted; usually ten times or more. The inoculated tubes were incubated at 37° C. for 48 hours, the amount of gas formation being noted at the end of 24 and 48 hours, according to the following symbols:

− Denoted no gas.
b Denoted gas not sufficient to fill the curved portion of the inverted tube.
± Denoted more gas than "b" but less than 10 per cent of the inverted tube.
+ Denoted between 10 per cent and 50 per cent of inverted tube.
# Denoted gas filling more than 50 per cent of inverted tube.

At the end of 48 hours' incubation, an Endo plate was streaked with a culture from the tube inoculated with the smallest portion of sample showing gas. In case this tube showed gas in a ± amount or less and had shown no gas at the end of the 24-hour period, a second Endo plate was streaked from the positive broth tube containing the next larger portion of sample. The Endo plates were then incubated for 18 to 24 hours at 37° C. If typical lactose-fermenting colonies appeared on these plates within 24 hours, the partially confirmed test was considered complete. If, however, the Endo plate failed to show such typical coli colonies, a colony most nearly resembling coli was picked from the plate to a lactose broth tube which was incubated for 48 hours, at 37° C. If this lactose broth tube showed gas in an amount equivalent to ± or more at the end of 24 or 48 hours, the partially confirmed test was considered complete. At the same time that the second broth tube was planted, a second Endo plate was streaked from the original broth tube and subsequently treated in the same manner as the first plate. In case either of these Endo plates on broth tubes gave typical results at the end of 24 or 48 hours, the partially confirmed test was considered complete.

b. Completely confirmed test.—For the complete confirmation of *B. coli*, a characteristic colonlike colony of the predominant variety appearing on the first Endo plate was transferred to a lactose broth fermentation tube, which was then incubated at 37° C., for 48 hours or less if gas in a ± amount or more was formed. If gas was formed, a second Endo plate was streaked from the tube to obtain a pure culture. If this second Endo plate showed a pure culture of colilike colonies, one such colony was transferred to an agar slant and incubated for 48 hours at 37° C. A gram stain was then made from the slant culture and examined to establish the presence of a gram negative, nonspore-bearing rod, colonlike in appearance. If the culture did not appear to be pure, the process was repeated until it was pure and the organism definitely classified. In case the Endo plate was negative but later the culture was partially confirmed, it was carried through just as though it had reacted typically on the Endo plate. The confirmed test for the *B. coli* group was considered positive when the partially confirmed organisms produced gas in lactose in ± or greater amounts when picked from aerobic plates, and which were demonstrated to be gram negative, nonspore-bearing rods. The organism was designated as not *B. coli* if the colony picked from an aerobic plate failed to produce gas in lactose broth in ± or greater amounts in 48 hours.

DIFFERENTIATION OF FECAL AND NONFECAL TYPES OF B. COLI

To determine the type of confirmed *B. coli* organisms, a typical colony was picked from the second Endo plate to a tube of dextrose-peptone-phosphate medium and incubated at 37° C. for 48 hours. At the end of the incubation period, the reaction of the culture to methyl red was noted. Cultures reacting acid were classified as of the fecal type, while those giving an alkaline or neutral reaction were considered of nonfecal origin.

Enumeration of B. coli.—For estimating the numbers of *B. coli* present in a given sample, the method prescribed in Standard Methods, 1920 edition, was followed.

CHAPTER V

SANITARY CHEMICAL ANALYSES

I. PRESENTATION OF DATA

In streams such as the Ohio River, where the degree of dilution is often enormous, it has been shown[1] that the organic pollution contributed by a city the size of metropolitan Cincinnati (population 595,000), under certain conditions of stream flow at least, can not be detected with any degree of certainty when expressed in terms of changes in the total nitrogen or permanganate oxygen consumed values. This is true because the errors to be expected in observations, amounting to about 10 per cent, are frequently greater than the proportional increase in these constituents resulting in the stream from the added pollution, especially at times when the dilution is high.

In the Illinois River, where the amounts of incoming polluting substances are much greater in proportion to the volume of stream flow than in the Ohio River and the resulting dilution effected is much less, measurable changes in these purely chemical measures of organic pollution might be expected to result, although the observed range and rapidity of variation would still be limited in proportion to errors of determination. With this reservation in mind, the scope of chemical analyses was restricted to those determinations which gave the most promise of reasonable interpretation. Such determinations are valuable, however, for the purpose of supplying comparative data of earlier studies and hence were included in the schedule of analyses of the Illinois River.

The sanitary chemical analyses comprised determinations of the free ammonia, Kjeldahl nitrogen, nitrogen oxides, and oxygen consumed of composite samples. The Kjeldahl nitrogen is generally considered to be a measure of the unstable and complex nitrogenous organic matter present in the sample, together with that in the form of ammonia, which latter represents an intermediate stage of conversion to more stable compounds. Hence the organic nitrogen is the difference between the Kjeldahl nitrogen and the free ammonia. The nitrogen oxides, sometimes designated as "mineral nitrogen," comprise nitrogen present as nitrites and nitrates. These being the more stable forms of nitrogenous compounds, represent the end products of nitrogenous organic matter that has undergone oxidation. The orderly increase of nitrogen oxides in a watercourse is therefore an indication of the progress of natural purification and transformation of polluting organic material into inoffensive forms. The total nitrogen is a measure of all forms of nitrogenous matter present, calculated by addition of the Kjeldahl nitrogen and nitrogen oxides. Hence, regardless of the changes in form of nitrogenous compounds of any sample, the total nitrogen present should not be affected except by that liberated in gaseous form. In stream surveys this determination is of value as a measure of the total contribution of nitrogen compounds to the watercourse above the point at which the sample is taken.

---

[1] A study of the pollution and natural purification of the Ohio River. II. Report on surveys and laboratory studies. Public Health Bulletin No. 143, U. S. Public Health Service, Washington, D. C., 1924.

The results obtained, because of their interest in connection with local Illinois River problems, and also for the purpose of complete presentation of the base data collected, are given in the following tables. Their more complete analysis and interpretation will not be attempted at this time.

As noted in the preceding chapter, samples for chemical analysis were regularly collected from selected sampling stations. From the daily samples thus received, aliquot portions were taken to make up, from each source, composite samples covering periods of 10 days. When the composites were complete, they were shipped to the Cincinnati laboratory for examination. These samples were preserved with sulphuric acid, which was selected for this purpose because of its freedom from interference with the oxygen-consumed test, and after the efficacy of the method had been carefully ascertained (see Appendix B). Amounts of sulphuric acid at first equal to approximately 500 parts per million and, later, 1,000 parts per million in the completed composite were used. Since the volumetric alkalinity of the untreated samples did not differ appreciably from 150 parts per million, the acidity of the treated samples was at first about 350 and later 850 parts per million. Colorimetric tests indicated that the hydrogen ion concentration of the preserved samples was about 1.8 and bacteriological examinations confirmed the assumption that under the conditions bacterial action was largely inhibited. However, growths were noted in practically all cases, but did not appear to affect the composition of the samples appreciably.

The three monthly composite samples from each sampling point were analyzed separately and the results obtained were combined to give the average content of the water for a given month. These monthly average analyses are presented in three series of tabulations, Tables Nos. 25, 26, and 27. In Table No. 25 all the analytical data for each sampling station are arranged in monthly average results, while in Tables Nos. 26 and 27 the same data are rearranged to give, for each of the constituents, all of the monthly average analytical values at the various sampling stations. The latter table gives for each constituent the values at all stations for all months, expressed in terms of quantity units[2]—which is in each case the product of the average monthly discharge in thousands of second-feet at the sampling station by the corresponding monthly average analytical value of the constituent in parts per million.

For purposes of comparison, averages of the above data are computed for the year and for seasonal periods. The yearly averages are derived from the data for the months of September, 1921, to August, 1922, inclusive; the summer averages are from the data for July, August, and September, 1921, and June, July, and August, 1922, while the winter averages are obtained from the results of December, 1921, and January, February, and March, 1922. The summer transitional averages are those of the months of October, 1921, and May, 1922, and the winter transitional figures are averages of November, 1921, and April, 1922.

TABLE No. 25.—*Summary of monthly average results of sanitary chemical analyses for each sampling station, arranged by months*

AT SUMMIT

Month	Discharge	Temperature of water	Constituents in parts per million				
			Free ammonia	Nitrogen oxides	Kjeldahl nitrogen	Total nitrogen	Oxygen consumed
	1,000 sec.-ft.	°*C.*					
1921							
September	8.23	19.2	1.70	0.00	3.00	3.00	....
October	8.54	12.4	1.55	.00	2.80	2.80	[a] 5.10
November	8.87	8.0	1.53	.47	3.73	4.20	[b] 8.00
December	8.67	4.2	1.27	.73	3.20	3.93	7.10
1922							
January	[a] 8.31	1.2	1.33	.30	2.13	2.43	6.63
February	8.38	2.0	1.60	.09	3.13	3.13	5.89
March	8.74	4.0	1.55	.00	4.20	4.20	8.30
April	8.45	8.3	1.67	.13	4.27	4.40	8.80
May	8.91	14.5	1.63	.00	2.80	2.80	6.47
June	9.37	19.7	1.23	.07	1.60	1.67	5.40
July	8.55	22.1	1.57	.03	2.47	2.50	5.67
August	8.82	23.1	1.63	.00	2.93	2.93	5.90
Averages							
September, 1921, to August, 1922	8.66	11.6	1.52	.14	3.02	3.17	6.66
Summer	8.74	21.0	1.53	.02	2.50	2.52	5.66
Winter	8.52	2.8	1.44	.28	3.16	3.42	6.98
Summer transitional	8.72	13.4	1.59	.00	2.80	2.80	5.78
Winter transitional	8.66	8.2	1.60	.30	4.00	4.30	8.40

[a] Abnormally high result of 26.2 omitted from average. If this value were included, average would be 15.15.

[b] Abnormally high result of 26 omitted from average. If this value were included, average would be 18.

---

[2] The "quantity unit" affords a convenient sized unit for the expression of results in terms of absolute quantities of constituents and is readily computed from the data of stream flow and chemical analyses. By the application of suitable conversion factors the quantity unit may be transformed into other units such as kilograms per day. Thus, remembering that 1 cubic foot = 28,317 cubic centimeters:

$$\text{Grams per day} = \frac{\text{parts per million} \times \text{second-feet} \times 60 \times 60 \times 24 \times 28{,}317}{1{,}000{,}000}$$

$$= \frac{\text{parts per million} \times \text{second-feet}}{1{,}000} \times \frac{60 \times 60 \times 24 \times 28{,}317}{1{,}000}$$

$$= \text{quantity units} \times 2{,}446{,}589$$

Therefore kilograms per day = quantity units × 2,446.589.

TABLE No. 25.—*Summary of monthly average results of sanitary chemical analyses for each sampling station, arranged by months*—Continued

AT STATION 202

Month	Discharge	Temperature of water	Constituents in parts per million				
			Free ammonia	Nitrogen oxides	Kjeldahl nitrogen	Total nitrogen	Oxygen consumed
	1,000 sec.-ft.	°*C.*					
1921							
August	8.46	22.7	1.73	0.00	3.53	3.53	7.47
September	8.23	20.1	1.63	.00	3.60	3.60	8.53
October	8.54	12.8	1.37	.10	3.13	3.23	8.00
November	8.87	7.4	1.37	.43	2.73	3.17	7.87
December	8.67	3.2	1.00	.80	3.33	4.13	8.43
1922							
January	8.31	0.3	1.40	.37	3.27	3.63	6.77
February	8.28	1.0	1.23	.00	3.47	3.47	6.80
March	8.74	3.7	1.10	.13	3.33	3.47	8.40
April	8.48	8.6	1.07	.37	2.80	3.17	7.53
May	8.91	15.0	1.97	.00	3.53	3.53	9.07
June	9.37	20.9	1.83	.00	3.13	3.13	6.00
July	8.85	22.4	1.93	.00	3.47	3.47	7.13
August	8.52	23.8	1.73	.00	4.53	4.53	8.07
Averages							
September, 1921, to August, 1922	8.66	11.7	1.47	.18	3.26	3.44	7.60
Summer	8.69	22.0	1.77	.00	3.65	3.65	7.44
Winter	8.53	2.1	1.18	.33	3.35	3.68	7.60
Summer transitional	8.73	14.4	1.80	.05	3.33	3.38	8.84
Winter transitional	8.68	8.0	1.21	.40	2.77	3.17	7.56

FOR THE DES PLAINES RIVER

Month	Discharge	Temperature of water	Free ammonia	Nitrogen oxides	Kjeldahl nitrogen	Total nitrogen	Oxygen consumed
1921							
August	0.011	21.9	0.63	0.10	1.93	2.03	7.67
September	.044	19.8	.60	.00	2.13	2.13	10.20
October	.198	10.8	.70	1.75	2.80	4.55	11.60
November	.896	4.5	.30	4.93	1.47	6.40	9.90
December	1.600	1.3	.23	6.27	2.00	8.27	8.58
1922							
January	.493	.0	.97	3.40	1.60	5.00	6.87
February	.121	.2	2.07	1.53	3.47	5.00	8.87
March	1.034	3.1	.53	2.07	2.53	4.60	12.40
April	1.598	9.0	.20	1.55	1.60	3.15	10.00
May	.251	18.2	.37	.70	2.07	2.77	10.07
June	.066	22.1	.60	.20	2.47	2.67	12.07
July	.040	22.9	.47	.13	2.20	2.33	12.88
August	.033	22.9	.40	.00	2.33	2.33	11.07
Averages							
September, 1921, to August, 1922	.533	11.2	.62	1.88	2.22	4.10	10.28
Summer	.039	21.9	.54	.00	2.21	2.20	10.67
Winter	.814	1.2	.95	3.32	2.40	5.72	9.08
Summer transitional	.224	14.5	.54	1.22	2.44	3.66	10.84
Winter transitional	1.247	6.8	.25	3.24	1.54	4.78	9.96

TABLE No. 25.—*Summary of monthly average results of sanitary chemical analyses for each sampling station, arranged by months*—Continued

AT STATION [illegible]

Month	Discharge	Temperature of water	Constituents in parts per million				
			Free ammonia	Nitrogen oxides	Kjeldahl nitrogen	Total nitrogen	Oxygen consumed
1921	*1,000 sec.-ft.*	*°C.*					
August	5.27	25.0	1.67	0.00	3.27	3.27	7.38
September	8.08	26.1	1.83	.00	3.60	3.60	6.80
October	8.78	13.7	1.57	.03	3.47	3.50	8.50
November	9.75	6.9	1.28	1.13	3.53	4.67	9.08
December	10.40	3.1	.87	2.17	3.00	5.17	8.67
1922							
January	8.70	.8	1.20	.67	2.87	3.53	6.33
February	8.33	1.8	.80	.30	3.07	3.37	8.60
March	9.78	4.6	1.00	.33	3.13	3.47	9.73
April	10.20	9.4	.97	.60	2.33	2.93	9.87
May	9.01	15.0	1.73	.00	2.40	2.40	7.27
June	9.26	20.5	1.80	.13	3.20	3.33	6.93
July	8.60	22.6	1.93	.03	3.67	3.70	6.80
August	8.26	23.7	1.90	.00	4.53	4.53	7.40
Averages							
September, 1921, to August, 1922	9.11	11.9	1.36	.44	3.24	3.68	8.11
Summer	8.55	22.0	1.77	.03	3.65	3.68	7.46
Winter	9.30	2.6	.97	.84	3.02	3.86	8.18
Summer transitional	8.90	14.4	1.65	.03	2.93	2.96	7.88
Winter transitional	9.98	8.2	1.10	.87	2.93	3.80	9.46

FOR THE KANKAKEE RIVER

Month	Discharge	Temperature of water	Free ammonia	Nitrogen oxides	Kjeldahl nitrogen	Total nitrogen	Oxygen consumed
1921							
August	0.706	23.6	0.10	0.07	0.67	0.73	5.23
September	1.280	25.3	.00	1.00	1.33	2.33	7.27
October	1.120	13.2	.07	1.23	.97	2.20	5.27
November	4.844	7.3	.08	3.63	1.13	4.77	5.10
December	5.805	4.0	.10	5.93	1.40	7.33	6.70
1922							
January	4.861	1.1	.10	3.70	1.27	4.97	5.90
February	2.871	1.6	.33	1.33	1.33	2.67	15.87
March	9.190	5.0	.20	2.90	2.07	4.97	10.13
April	10.610	10.7	.17	2.08	1.80	3.88	14.60
May	5.160	19.7	.17	1.30	1.33	2.63	9.67
June	1.925	24.5	.17	.57	1.13	1.70	7.40
July	1.022	24.9	.23	.33	.93	1.27	6.80
August	.713	24.5	.13	.00	1.07	1.07	5.67
Averages							
September, 1921, to August, 1922	4.947	12.3	.16	2.00	1.30	3.30	8.54
Summer	1.119	24.2	.13	.39	1.03	1.42	6.31
Winter	5.934	2.9	.23	3.44	1.52	4.96	9.63
Summer transitional	3.140	16.4	.12	1.32	1.10	2.42	7.47
Winter transitional	12.227	9.0	.10	2.83	1.47	4.30	11.35

TABLE No. 25.—*Summary of monthly average results of sanitary chemical analyses for each sampling station, arranged by months*—Continued

AT STATION 2[illegible]

Month	Discharge	Temperature of water	Constituents in parts per million				
			Free ammonia	Nitrogen oxides	Kjeldahl nitrogen	Total nitrogen	Oxygen consumed
	1,000 sec.-ft.	*° C.*					
1921							
August	9.13	23.1	1.90	0.07	4.33	4.40	7.97
September	9.92	21.0	1.58	.00	3.47	3.47	8.38
October	10.50	13.5	1.67	.10	3.40	3.50	9.13
November	15.20	7.6	1.17	1.37	3.13	4.50	8.20
December	17.90	3.7	.97	2.60	2.93	5.53	7.60
1922							
January	14.00	1.1	1.33	1.27	3.20	4.47	10.31
February	12.30	1.8	1.17	.40	3.87	4.27	8.53
March	19.90	4.7	.73	1.37	3.67	5.03	10.30
April	23.20	10.3	.87	1.23	2.33	3.57	13.00
May	15.20	16.3	1.27	.13	2.53	2.67	8.27
June	11.80	20.6	1.30	.17	1.27	1.43	7.97
July	10.30	23.7	1.77	.00	2.40	2.40	7.40
August	9.08	23.5	1.60	.00	2.93	2.93	6.13
Averages							
September, 1921, to August, 1922	15.00	12.2	1.23	.72	2.93	3.66	8.70
Summer	10.16	22.2	1.64	.06	2.87	2.92	7.84
Winter	16.03	2.8	1.08	1.41	3.42	4.83	9.15
Summer transitional	12.55	14.9	1.57	.12	2.96	3.08	8.70
Winter transitional	24.23	9.0	.87	1.30	2.73	4.03	10.60

AT STATION 240

Month	Discharge	Temperature of water	Free ammonia	Nitrogen oxides	Kjeldahl nitrogen	Total nitrogen	Oxygen consumed
1921							
August	9.20	24.0	2.00	0.09	3.30	3.39	5.45
September	10.00	21.7	1.77	.00	3.40	3.40	6.30
October	10.60	14.0	1.43	.23	3.33	3.57	9.07
November	15.80	6.1	.93	2.07	2.23	4.30	7.93
December	18.10	2.6	.73	3.00	2.33	5.33	8.97
1922							
January	14.10	.5	1.03	1.37	3.00	4.37	7.10
February	12.50	.0	1.40	.37	3.07	3.43	7.13
March	20.10	3.2	.90	1.50	2.47	3.97	9.93
April	34.05	9.2	.37	1.77	2.33	4.10	14.73
May	15.40	(17.0)	.90	.50	2.27	2.77	6.80
June	11.90	21.3	1.03	.23	2.20	2.43	7.67
July	16.40	24.0	1.93	.06	2.10	2.16	6.33
August	9.67	23.4	1.77	.09	3.20	3.29	8.20
Averages							
September, 1921, to August, 1922	15.19	11.9	1.17	.92	2.72	3.64	8.86
Summer	10.28	23.0	1.70	.06	3.03	3.07	7.50
Winter	16.20	1.6	.99	1.56	2.73	4.28	8.20
Summer transitional	13.00	15.5	1.16	.37	2.80	3.17	8.94
Winter transitional	24.75	7.6	.65	1.92	2.28	4.20	11.23

TABLE NO. 25.—*Summary of monthly average results of sanitary chemical analyses for each sampling station, arranged by months*—Continued

FOR THE FOX RIVER

Month	Discharge	Temperature of water	Constituents in parts per million				
			Free ammonia	Nitrogen oxides	Kjeldahl nitrogen	Total nitrogen	Oxygen consumed
	1,000 sec.-ft.	°*C.*					
1921							
July	0.225	25.6	0.17	0.08	1.40	1.48	7.57
August	.248	24.9	.10	.08	1.50	1.57	8.20
September	.807	21.7	.13	.13	2.20	2.33	10.98
October	1.659	12.8	.08	.97	1.33	2.30	8.73
November	2.165	4.7	.20	2.30	1.07	3.37	9.73
December	3.594	1.9	.17	5.47	1.60	7.07	8.37
1922							
January	2.260	.5	.48	3.30	1.67	4.97	7.12
February	1.140	.0	.30	1.23	1.37	2.60	7.47
March	3.286	5.4	.47	1.44	2.13	3.57	12.00
April	4.586	9.0	.20	1.77	2.00	3.77	11.38
May	1.461	15.0	.10	.80	.87	1.67	8.12
June	.621	20.1	.10	.37	.90	1.27	6.40
July	.531	24.7	.20	.20	1.20	1.40	6.73
August	.227	20.4	.10	.03	1.47	1.50	6.67
Averages							
September, 1921, to August, 1922	1.865	11.9	.23	1.30	1.60	2.90	9.00
Summer	.460	23.8	.13	.12	1.46	1.58	7.02
Winter	2.557	2.0	.30	2.86	1.67	4.53	8.74
Summer transitional	1.570	14.4	.08	.88	1.10	1.98	8.43
Winter transitional	3.261	6.8	.20	2.03	1.34	3.37	10.68

AT STATION 227

Month	Discharge	Temperature of water	Free ammonia	Nitrogen oxides	Kjeldahl nitrogen	Total nitrogen	Oxygen consumed
1921							
July	9.40	26.3	1.67	0.00	3.20	3.20	6.67
August	9.48	23.4	1.70	.00	3.00	3.00	7.10
September	10.90	20.9	1.53	.10	3.33	3.43	7.40
October	12.70	13.4	1.23	.30	3.00	3.30	7.67
November	17.80	6.4	.87	1.70	2.27	3.97	8.20
December	21.90	2.3	.73	3.17	2.33	5.50	8.73
1922							
January	16.50	.4	1.07	1.67	2.60	4.27	7.53
February	13.70	.9	.97	.73	2.53	3.27	8.40
March	23.40	4.8	.63	1.73	2.60	4.33	11.07
April	39.00	10.1	.37	1.93	2.13	4.07	12.07
May	17.00	17.2	.97	.40	2.13	2.53	8.47
June	12.60	21.2	1.20	.13	1.67	1.80	7.27
July	10.90	22.9	1.73	.00	2.93	2.93	7.73
August	10.00	23.7	1.73	.00	3.20	3.20	7.27
Averages							
September, 1921, to August, 1922	17.17	12.0	1.09	.99	2.56	3.55	8.55
Summer	10.86	23.1	1.59	.04	2.89	2.93	7.27
Winter	18.88	2.1	.85	1.82	2.52	4.34	8.06
Summer transitional	14.65	15.3	1.10	.35	2.56	2.91	8.07
Winter transitional	28.40	8.2	.62	1.52	2.50	4.02	10.68

TABLE No. 25.—*Summary of monthly average results of sanitary chemical analyses for each sampling station, arranged by months*—Continued

FOR THE VERMILION RIVER

Month	Discharge	Temperature of water	Constituents in parts per million				
			Free ammonia	Nitrogen oxides	Kjeldahl nitrogen	Total nitrogen	Oxygen consumed
	1,000 sec.-ft.	°C.					
1921							
July	0.036	28.4	0.57	0.60	2.33	2.38	7.13
August	.332	24.4	.70	.09	2.00	2.09	7.10
September	.290	[illegible]	.40	.90	2.20	3.10	8.60
October	.187	15.0	.00	1.77	1.20	2.97	14.33
November	1.020	7.1	.10	2.80	1.40	4.00	6.79
December	1.270	2.8	.40	5.67	1.55	7.20	4.97
1922							
January	.443	.5	.55	4.10	1.53	5.63	5.70
February	.705	.9	.60	3.20	1.33	4.53	9.83
March	2.560	4.7	.23	4.67	1.93	6.60	12.73
April	4.520	10.2	.13	3.77	2.20	[illegible]	15.47
May	.775	19.3	.10	2.63	.53	4.17	3.67
June	.185	24.9	.17	1.90	1.00	2.80	4.09
July	.093	25.6	.33	.67	1.27	2.13	5.33
August	.001	24.8	.43	.10	1.40	1.30	6.13
Averages							
September, 1921, to August, 1922	1.074	13.1	.27	2.61	1.46	4.07	7.91
Summer	.066	25.0	.46	.61	1.70	2.31	4.26
Winter	1.245	2.2	.40	4.46	1.56	6.04	5.15
Summer transitional	.461	17.2	.06	2.20	.86	3.08	9.09
Winter transitional	2.770	8.6	.12	2.66	1.50	4.46	10.08

AT STATION 1[illegible]

Month	Discharge	Temperature of water	Free ammonia	Nitrogen oxides	Kjeldahl nitrogen	Total nitrogen	Oxygen consumed
1921							
July	9.96	27.7	1.80	0.00	2.90	2.80	5.63
August	9.75	24.2	1.80	.00	3.20	3.20	5.37
September	11.50	21.6	1.50	.17	2.93	3.10	6.90
October	12.60	13.0	1.00	.53	2.20	2.73	7.40
November	17.90	7.3	.70	1.63	2.13	3.77	6.77
December	24.00	2.9	.50	3.63	1.80	5.43	7.73
1922							
January	18.20	.9	.93	2.13	2.27	4.40	[illegible]
February	15.20	1.2	1.07	.67	2.67	3.33	[illegible]
March	25.10	4.5	.67	1.70	2.33	4.07	[illegible]
April	46.70	10.4	.37	1.80	1.73	3.53	5.60
May	20.20	18.6	.73	.90	2.07	2.97	7.60
June	14.40	23.5	1.08	.28	2.07	2.30	4.93
July	11.22	24.2	1.73	.00	2.73	2.73	6.60
August	10.10	25.1	1.93	.00	3.40	3.40	5.40
Averages							
September, 1921, to August, 1922	18.46	12.8	1.01	1.12	2.34	3.46	7.06
Summer	11.16	24.4	1.62	.07	2.55	2.92	6.24
Winter	20.63	2.4	.79	2.03	2.27	4.30	7.92
Summer transitional	16.40	15.8	.88	.72	2.13	2.85	7.50
Winter transitional	31.90	8.8	.54	1.72	1.93	3.65	9.18

TABLE No. 25.—*Summary of monthly average results of sanitary chemical analyses for each sampling station, arranged by months*—Continued

AT STATION 179

Month	Discharge	Temperature of water	Constituents in parts per million				
			Free ammonia	Nitrogen oxides	Kjeldahl nitrogen	Total nitrogen	Oxygen consumed
1921	*1,000 sec.-ft.*	°*C.*					
August	9.80	23.8	1.35	0.00	3.10	3.10	4.75
September	11.70	21.4	1.63	.07	2.73	2.80	5.57
October	12.80	13.2	1.13	.60	2.27	2.87	5.40
November	16.60	7.5	.90	1.53	1.77	3.40	6.07
December	24.60	3.9	.73	3.63	1.87	5.50	6.13
1922							
January	19.50	.1	.90	2.23	2.07	4.30	6.03
February	15.60	.5	1.17	.57	2.47	3.03	5.83
March	23.70	4.4	.93	1.43	2.53	3.97	9.07
April	46.70	10.3	.47	1.93	1.60	3.73	9.33
May	22.60	18.4	.67	.80	1.67	2.47	7.47
June	15.90	23.5	.97	.33	1.80	2.13	5.80
July	11.42	24.6	1.73	.00	2.93	2.93	4.60
August	10.10	24.5	1.87	.00	3.27	3.27	4.80
Averages							
September, 1921, to August, 1922	19.27	12.7	1.09	1.10	2.27	3.37	6.34
Summer	11.80	23.6	1.61	.08	2.76	2.84	5.10
Winter	20.85	2.2	.93	1.97	2.24	4.20	6.77
Summer transitional	17.70	15.8	.90	.70	1.97	2.67	6.44
Winter transitional	31.65	8.9	.68	1.78	1.78	3.56	7.70

AT STATION 166

Month	Discharge	Temperature of water	Free ammonia	Nitrogen oxides	Kjeldahl nitrogen	Total nitrogen	Oxygen consumed
1921							
July	10.10	28.3	1.53	0.00	2.73	2.73	5.10
August	9.96	24.0	1.67	.07	2.80	2.87	5.23
September	11.80	22.0	1.50	.13	2.80	2.93	6.00
October	12.80	13.2	.93	.80	1.87	2.67	5.33
November	16.10	8.0	.83	1.50	1.87	3.37	6.33
December	24.90	3.9	.70	3.57	1.67	5.23	5.00
1922							
January	20.10	.2	.80	2.40	1.80	4.20	5.00
February	15.80	.9	1.17	.67	2.20	2.87	4.93
March	23.10	5.5	.83	1.33	1.80	3.13	6.87
April	47.20	11.2	.37	1.90	.93	2.83	7.20
May	23.60	19.3	.37	1.17	1.27	2.43	6.67
June	16.50	24.2	.57	.37	1.87	2.23	5.73
July	11.50	24.8	1.43	.07	2.47	2.53	5.27
August	10.10	24.7	1.43	.07	2.73	2.80	6.07
Averages							
September, 1921, to August, 1922	19.46	13.2	.91	1.16	1.94	3.10	5.87
Summer	11.66	24.7	1.36	.12	2.57	2.69	5.57
Winter	20.98	2.6	.88	1.99	1.87	3.86	5.45
Summer transitional	18.20	16.2	.65	.98	1.57	2.55	6.00
Winter transitional	31.65	9.6	.60	1.70	1.40	3.10	6.76

TABLE No. 25.—*Summary of monthly average results of sanitary chemical analyses for each sampling station, arranged by months*—Continued

AT STATION 148

Month	Discharge	Temperature of water	Constituents in parts per million				
			Free ammonia	Nitrogen oxides	Kjeldahl nitrogen	Total nitrogen	Oxygen consumed
1921	*1,000 sec.-ft.*	°*C.*					
July	10.20	28.4	1.30	0.00	2.87	2.87	6.17
August	10.00	24.4	1.47	.13	2.80	2.93	5.47
September	11.90	22.9	1.37	.07	2.87	2.93	6.67
October	12.90	14.0	.80	.83	1.67	[illegible]	5.53
November	16.20	7.4	.77	1.33	1.73	[illegible]	5.77
December	25.20	3.8	.67	3.47	1.53	5.00	4.67
1922							
January	20.60	1.0	.70	2.60	1.80	4.40	8.10
February	16.10	.5	1.13	.67	2.27	2.93	5.20
March	23.50	4.9	.80	1.23	2.07	3.30	7.47
April	48.00	9.6	.27	1.93	1.00	2.93	7.57
May	24.60	18.5	.23	1.43	1.20	2.63	7.60
June	17.00	24.8	.37	.53	.73	1.27	6.73
July	11.70	25.8	1.03	.30	2.47	2.77	6.60
August	10.10	25.4	1.13	.13	3.20	3.33	6.47
Averages							
September, 1921, to August, 1922	19.82	13.2	.77	1.21	1.88	3.09	6.59
Summer	11.82	25.3	1.11	.19	2.49	2.68	6.38
Winter	21.35	2.6	.82	1.99	1.92	3.91	6.41
Summer transitional	18.75	16.2	.52	1.13	1.44	2.57	6.56
Winter transitional	32.10	8.5	.52	1.63	1.36	3.00	6.82

FOR THE MACKINAW RIVER

Month	Discharge	Temperature of water	Free ammonia	Nitrogen oxides	Kjeldahl nitrogen	Total nitrogen	Oxygen consumed
1921							
July	0.104	25.2	0.33	0.37	2.00	2.37	6.17
August	.236	22.6	.30	.40	2.73	3.13	15.20
September	.830	21.0	.07	1.17	1.67	2.83	10.67
October	.295	13.3	.60	1.47	.80	2.27	6.37
November	.822	7.2	.13	1.73	1.00	2.73	5.73
December	1.140	4.2	.27	4.07	1.53	5.60	6.27
1922							
January	.625	1.7	.20	3.40	1.90	5.30	8.20
February	.618	.7	.60	1.50	2.13	3.63	9.90
March	1.896	5.6	.27	2.80	2.40	5.20	12.40
April	3.715	10.4	.27	1.83	1.00	2.83	7.73
May	.800	18.4	.10	2.10	1.20	3.30	8.93
June	.321	24.2	.07	1.33	.87	2.20	5.20
July	.121	25.2	.10	.73	1.07	1.80	5.00
August	.052	23.5	.10	.13	1.47	1.60	5.40
Averages							
September, 1921, to August, 1922	.936	13.0	.18	1.86	1.42	3.27	7.57
Summer	.277	[illegible]	.16	.69	1.64	2.33	7.94
Winter	1.070	3.0	.34	2.94	1.99	4.93	2.19
Summer transitional	.548	15.8	.05	1.78	1.00	2.78	7.15
Winter transitional	2.268	8.8	.20	1.78	1.00	2.78	6.60

TABLE No. 25.—*Summary of monthly average results of sanitary chemical analyses for each sampling station, arranged by months*—Continued

FOR THE SPOON RIVER

Month	Discharge	Temperature of water	Constituents in parts per million				
			Free ammonia	Nitrogen oxides	Kjeldahl nitrogen	Total nitrogen	Oxygen consumed
	1,000 sec.-ft.	°*C.*					
1921							
July	0.195	28.0	0.47	0.80	2.47	3.27	11.20
August	.397	23.6	.20	.63	1.87	2.50	10.60
September	.735	23.3	.10	.93	3.13	4.07	17.47
October	.332	12.6	.03	1.27	1.47	2.73	9.53
November	.390	6.0	.20	1.60	1.47	3.07	8.80
December	.808	2.3	.27	3.43	1.27	4.70	7.67
1922							
January	.765	.3	.70	2.60	1.93	4.53	7.77
February	1.312	1.3	.67	1.87	1.93	3.80	10.63
March	1.642	5.4	.57	1.63	2.93	4.57	16.27
April	2.798	12.0	.40	2.20	.40	2.60	7.20
May	1.323	21.1	.15	1.40	3.50	4.90	16.80
June	.497	25.1	.10	1.07	.40	1.47	6.20
July	1.023	25.6	.17	.87	3.27	4.13	14.33
August	.103	25.9	.17	.03	1.80	1.83	5.27
Averages							
September, 1921, to August, 1922	.978	13.4	.29	1.58	1.96	3.54	10.55
Summer	.492	25.2	.20	.72	2.16	2.88	10.84
Winter	1.132	2.3	.55	2.38	2.02	4.40	10.59
Summer transitional	.828	16.8	.09	1.34	2.48	3.82	12.66
Winter transitional	1.506	15.0	.30	1.90	.94	2.84	7.85
AT STATION 101							
1921							
July	10.70	28.2	0.80	0.35	2.10	2.45	6.40
August	10.30	25.2	.83	.73	2.07	2.80	5.87
September	12.60	24.3	.90	.53	1.93	2.47	6.20
October [3]	13.80	14.7	1.07	1.10	3.27	4.37	7.80
November	16.60	11.4	.60	1.00	1.40	2.40	6.80
December	27.70	....	....	....	....	....	....
1922							
January	24.20	....	....	....	....	....	....
February	18.60	....	....	....	....	....	....
March	26.50	....	....	....	....	....	....
April	54.70	....	....	....	....	....	....
May	32.20	....	....	....	....	....	....
June	20.50	....	....	....	....	....	....
July	13.20	....	....	....	....	....	....
August	10.40	....	....	....	....	....	....
FOR THE SANGAMON RIVER							
1921							
July	0.743	28.2	0.60	0.35	1.80	2.15	5.65
August	1.133	25.0	.90	.47	2.73	3.20	11.47
September	1.972	24.5	1.10	.60	2.40	3.30	13.13
October	1.312	14.6	.23	1.10	1.00	2.10	5.57
November	3.594	11.4	.40	1.20	1.20	2.40	6.80
FOR CROOKED CREEK							
1921							
July	0.192	28.6	0.25	0.45	2.10	2.55	6.95
August	.565	24.8	.13	.53	1.87	2.40	12.47
September	1.505	22.8	.65	.40	2.47	2.50	21.87
October	.319	14.7	.07	1.03	1.73	2.77	10.27
November	.313	11.6	.20	1.30	1.20	2.50	11.90

[3] Contains one abnormally polluted sample.

TABLE No. 25.—*Summary of monthly average results of sanitary chemical analyses for each sampling station, arranged by months*—Continued

AT STATION 77

Month	Discharge	Temperature of water	Constituents in parts per million				
			Free ammonia	Nitrogen oxides	Kjeldahl nitrogen	Total nitrogen	Oxygen consumed
	1,000 sec.-ft.	*° C.*					
1921							
July	12.10	28.2	0.65	0.30	2.00	2.30	5.70
August	12.00	25.1	.70	.53	1.60	2.13	12.27
September	15.60	23.6	.50	.73	1.67	2.40	7.33
October	15.50	14.8	.27	1.07	1.33	2.40	5.87
November	18.10	11.6	.20	1.20	1.20	2.40	7.00

AT STATION 43

Month	Discharge	Temperature of water	Free ammonia	Nitrogen oxides	Kjeldahl nitrogen	Total nitrogen	Oxygen consumed
1921							
July	12.30	29.5	0.10	0.87	1.53	2.40	6.43
August	12.30	25.4	.10	1.10	1.73	2.83	6.07
September	16.00	22.7	.10	1.03	2.00	3.03	11.20
October	15.80	14.1	.03	1.27	1.40	2.67	6.87
November	18.30	7.5	.53	1.30	1.73	3.03	6.00
December	33.70	4.2	.40	3.33	1.47	4.80	6.27
1922							
January	26.90	----------	.63	2.70	1.73	4.43	7.30
February	21.90	1.7	.80	1.03	2.00	3.03	8.54
March	36.70	5.8	.53	1.07	2.47	3.53	11.73
April	89.40	9.0	.20	1.90	1.20	3.10	6.40
May	51.80	20.2	.13	1.30	.40	1.70	6.00
June	26.00	25.6	.07	.53	.67	1.20	5.00
July	16.10	26.2	.13	.77	1.07	1.84	7.33
August	12.10	26.4	.13	.70	1.13	1.83	5.27
Averages							
September, 1921, to August, 1922	30.56	14.9	.31	1.41	1.44	2.85	7.42
Summer	15.80	26.0	.10	.83	1.36	2.19	6.88
Winter	30.30	3.9	.59	2.03	1.92	3.95	8.46
Summer transitional	33.80	17.2	.08	1.28	.90	2.15	6.74
Winter transitional	53.85	8.2	.36	1.60	1.46	3.06	6.50

AT STATION 26

Month	Discharge	Temperature of water	Free ammonia	Nitrogen oxides	Kjeldahl nitrogen	Total nitrogen	Oxygen consumed
1921							
July	12.40	29.3	0.13	0.73	1.20	1.93	5.87
August	12.40	25.7	.03	1.27	1.60	2.87	6.77
September	16.20	23.6	.07	1.23	1.67	2.90	8.67
October	15.90	14.5	.10	1.20	1.27	2.47	5.80
November	18.40	7.4	.43	1.33	1.60	2.93	6.67
December	34.10	4.3	.33	3.20	1.47	4.67	6.30
1922							
January	29.30	----------	.60	2.70	2.60	5.30	14.03
February	22.10	1.9	.93	.97	2.47	3.43	15.67
March	37.20	6.3	.50	.93	1.60	2.53	10.80
April	91.20	9.0	.10	1.90	.60	2.50	7.00
May	53.00	20.1	.10	1.33	.73	2.06	6.60
June	26.40	25.9	.07	.70	.53	1.23	4.27
July	16.30	26.2	.10	.77	.87	1.63	6.27
August	12.20	26.0	.03	.73	.93	1.67	4.47
Averages							
September, 1921, to August, 1922	31.02	15.0	.28	1.42	1.36	2.78	8.05
Summer	15.98	26.1	.07	.90	1.13	2.03	5.89
Winter	30.68	4.2	.59	1.95	2.04	3.99	11.70
Summer transitional	34.45	17.3	.10	1.27	1.00	2.27	6.20
Winter transitional	54.80	8.2	.28	1.62	1.10	2.72	6.84

TABLE No. 25.—*Summary of monthly average results of sanitary chemical analyses for each sampling station, arranged by months*—Continued

FOR MACOUPIN CREEK

Month	Discharge	Temperature of water	Constituents in parts per million				
			Free ammonia	Nitrogen oxides	Kjeldahl nitrogen	Total nitrogen	Oxygen consumed
	1,000 sec.-ft.	°*C.*					
1921							
July	0.089	27.5	0.07	0.73	1.73	2.47	9.10
August	.226	24.8	.07	.27	1.33	1.60	10.10
September	.281	22.7	.30	.37	1.73	2.10	12.23
October	.085	13.4	.00	.60	1.33	1.93	9.33
November	.767	7.6	.23	.53	1.67	2.20	9.67
December	.830	5.6	.30	1.00	1.20	2.20	7.20
1922							
January	.640	------	------	------	------	------	------
February	.400	3.1	.30	1.00	1.60	2.60	7.60
March	4.367	7.0	.20	.93	1.67	2.60	14.40
April	5.605	12.0	.20	.50	1.60	2.10	15.40
May	.344	20.6	.10	.20	.60	.80	6.07
June	.091	25.3	.03	.07	.47	.53	4.27
July	.025	25.6	.07	.10	.40	.50	5.00
August	.019	25.1	.07	.10	1.20	1.30	5.20
Averages							
September, 1921, to August, 1922	1.085	15.3	.15	.49	1.22	1.71	8.68
Summer	.114	25.2	.10	.27	1.13	1.42	7.67
Winter	1.314	5.2	.20	.98	1.49	2.47	9.40
Summer transitional	.214	17.0	.05	.40	.96	1.36	7.70
Winter transitional	3.186	9.8	.22	.53	1.63	2.15	12.57

FOR THE MISSISSIPPI RIVER AT HAMBURG, ILL.

1921							
July	------	------	------	------	------	------	------
August	------	25.0	------	------	------	------	------
September	------	24.0	------	------	------	------	------
October	------	15.1	------	------	------	------	------
November	------	7.8	------	------	------	------	------
December	------	2.7	------	------	------	------	------
1922							
January	------	.3	------	------	------	------	------
February	------	1.1	------	------	------	------	------
March	------	5.3	------	------	------	------	------
April	------	10.0	------	------	------	------	------
May	------	20.2	------	------	------	------	------
June	------	25.3	------	------	------	------	------
July	------	25.5	------	------	------	------	------
August	------	25.8	------	------	------	------	------

TABLE No. 26.—*Summary of monthly average results of sanitary chemical analyses for each constituent, expressed in parts per million, arranged by sampling stations and months*

[Results in parts per million]

A. FREE AMMONIA

Sampling station	1921						1922							
	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
Summit	------	------	1.70	1.66	1.53	1.27	1.33	1.60	1.55	1.67	1.03	1.23	1.57	1.63
292	------	1.73	1.63	1.37	1.37	1.00	1.40	1.23	1.10	1.07	1.97	1.53	1.93	1.73
Des Plaines	------	.63	.60	.70	.30	.23	.97	2.07	.53	.20	.37	.60	.47	.40
286	------	1.67	1.53	1.57	1.23	.87	1.20	.30	1.00	.97	1.73	1.50	1.93	1.90
Kankakee	------	.10	.00	.07	.03	.10	.10	.53	.20	.17	.17	.17	.23	.13
263	------	1.80	1.93	1.87	1.17	.57	1.33	1.17	.73	.57	1.27	1.20	1.77	1.60
240	------	2.00	1.77	1.43	.93	.73	1.03	1.40	.60	.37	.90	1.03	1.93	1.77
Fox	0.17	.10	.13	.03	.20	.17	.43	.50	.47	.20	.10	.10	.20	.10
227	1.67	1.70	1.53	1.23	.87	.73	1.07	.97	.63	.37	.97	1.20	1.73	1.73
Vermilion	.87	.70	.40	.00	.10	.40	.55	.40	.23	.13	.10	.17	.33	.43
196	1.50	1.50	1.50	1.00	.70	.50	.93	1.07	.67	.37	.73	1.03	1.73	1.63
179	------	1.55	1.63	1.13	.90	.73	.90	1.17	.33	.47	.67	.97	1.73	1.87
166	1.53	1.67	1.50	.93	.83	.70	.80	1.17	.83	.37	.37	.57	1.43	1.43
148	1.30	1.47	1.37	.80	.77	.67	.70	1.13	.80	.27	.23	.37	1.03	1.13
Mackinaw	.33	.30	.07	.00	.13	.27	.20	.60	.27	.27	.10	.07	.10	.10
Spoon	.47	.20	.10	.03	.20	.27	.70	.67	.57	.40	.15	.10	.17	.17
101	.80	.53	.90	1.07	.60	------	------	------	------	------	------	------	------	------
Sangamon	.60	.90	1.10	.23	.40	------	------	------	------	------	------	------	------	------
Crooked Creek	.25	.13	.65	.07	.20	------	------	------	------	------	------	------	------	------
77	.65	.70	.50	.27	.20	------	------	------	------	------	------	------	------	------
43	.10	.10	.10	.03	.53	.40	.63	.80	.53	.20	.13	.07	.13	.13
26	.12	.03	.07	.10	.43	.33	.60	.93	.50	.10	.10	.07	.10	.03
Macoupin	.07	.07	.30	.00	.23	.20	------	.20	.20	.20	.10	.03	.07	.07

B. KJELDAHL NITROGEN

Sampling station	1921						1922							
	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
Summit	------	------	3.00	2.80	3.73	3.20	2.13	3.13	4.20	4.27	2.80	1.60	2.47	2.93
292	------	3.53	3.60	3.13	2.73	3.33	3.27	3.47	3.33	2.80	3.53	3.13	3.47	4.53
Des Plaines	------	1.93	2.13	2.80	1.47	2.00	1.60	3.47	2.53	1.60	2.07	2.47	2.20	2.33
286	------	3.27	3.60	3.47	3.53	3.00	2.87	3.07	3.13	2.33	2.40	3.20	3.67	4.53
Kankakee	------	.67	1.33	.87	1.10	1.40	1.27	1.33	2.07	1.80	1.33	1.13	.93	1.07
263	------	4.33	3.47	3.40	3.13	2.93	2.20	3.87	3.67	2.33	2.53	1.27	2.40	2.93
240	------	3.50	3.40	3.33	2.23	2.33	3.00	3.07	2.47	2.33	2.27	2.20	2.80	3.20
Fox	1.40	1.53	2.20	1.33	1.07	1.60	1.67	1.27	2.13	2.00	.87	.93	1.20	1.47
227	3.20	3.00	3.33	3.00	2.27	2.33	2.60	2.53	2.60	2.13	2.13	1.67	2.93	3.20
Vermilion	2.33	2.00	2.20	1.20	1.40	1.53	1.53	1.33	1.93	2.20	.53	1.00	1.27	1.40
196	2.80	3.20	2.93	2.20	2.13	1.80	2.27	2.67	2.33	1.73	2.07	2.07	2.73	3.40
179	------	3.10	2.73	2.27	1.77	1.87	2.07	2.47	2.53	1.80	1.67	1.80	2.93	3.27
166	2.73	2.80	2.80	1.87	1.87	1.67	1.80	2.20	1.80	.93	1.27	1.87	2.47	2.73
148	2.87	2.80	2.87	1.67	1.73	1.53	1.80	2.27	2.07	1.00	1.20	.73	2.47	3.20
Mackinaw	2.00	2.73	1.67	.80	1.00	1.53	1.90	2.13	2.40	1.00	1.20	.87	1.07	1.47
Spoon	2.47	1.87	3.13	1.47	1.47	1.27	1.93	1.93	2.93	.40	3.50	.40	3.27	1.80
101	2.10	2.07	1.93	3.27	1.40	------	------	------	------	------	------	------	------	------
Sangamon	1.80	2.73	2.40	1.00	1.20	------	------	------	------	------	------	------	------	------
Crooked Creek	2.10	1.87	2.47	1.73	1.20	------	------	------	------	------	------	------	------	------
77	2.00	1.60	1.67	1.33	1.20	------	------	------	------	------	------	------	------	------
43	1.53	1.73	2.00	1.40	1.73	1.47	1.73	2.00	2.47	1.20	.40	.67	1.07	1.13
26	1.20	1.60	1.67	1.27	1.60	1.47	2.60	2.47	1.60	.60	.73	.53	.87	.93
Macoupin	1.73	1.33	1.73	1.33	1.67	1.20	------	1.60	1.67	1.60	.60	.47	.40	1.20

C. NITROGEN OXIDES

Sampling station	1921						1922							
	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
Summit	------	------	0.00	0.00	0.47	0.73	0.30	0.00	0.00	0.13	0.00	0.07	0.03	0.00
292	------	0.00	.00	.10	.43	.80	.37	.00	.13	.37	.00	.00	.00	.00
Des Plaines	------	.10	.00	1.75	4.93	6.27	3.40	1.53	2.07	1.55	.70	.20	.13	.00
286	------	.00	.00	.03	1.13	2.17	.67	.20	.33	.60	.00	.13	.03	.00
Kankakee	------	.07	1.00	1.33	3.63	5.93	3.70	1.33	2.80	2.03	1.30	.57	.33	.00
263	------	.07	.00	.10	1.37	2.60	1.27	.40	1.37	1.23	.13	.17	.00	.00
240	------	.00	.00	.23	2.07	3.00	1.37	.37	1.50	1.77	.50	.23	.03	.00
Fox	0.03	.03	.13	.97	2.30	5.47	3.30	1.23	1.43	1.77	.80	.33	.20	.03
227	.00	.00	.10	.30	1.70	3.17	1.67	.73	1.73	1.93	.40	.13	.00	.00
Vermilion	.00	.00	.90	1.77	2.60	5.67	4.10	3.20	4.87	2.77	2.63	1.80	.87	.10
196	.00	.00	.17	.53	1.63	3.63	2.13	.67	1.70	1.80	.90	.23	.00	.00
179	------	.00	.07	.60	1.63	3.63	2.23	.57	1.43	1.93	.80	.33	.00	.00
166	.00	.07	.13	.80	1.50	3.57	2.40	.67	1.33	1.90	1.17	.37	.07	.07
148	.00	.13	.07	.83	1.33	3.47	2.60	.67	1.23	1.95	1.43	.53	.30	.13
Mackinaw	.37	.40	1.17	1.47	1.73	4.07	3.40	1.50	2.80	1.83	2.10	1.33	.73	.13
Spoon	.80	.63	.93	1.27	1.60	3.43	2.60	1.87	1.63	2.20	1.40	1.07	.87	.03
101	.35	.73	.53	1.10	1.00	------	------	------	------	------	------	------	------	------
Sangamon	.35	.47	.60	1.10	1.20	------	------	------	------	------	------	------	------	------
Crooked Creek	.45	.53	.40	1.03	1.30	------	------	------	------	------	------	------	------	------
77	.30	.53	.73	1.07	1.20	------	------	------	------	------	------	------	------	------
43	.87	1.10	1.03	1.27	1.30	3.33	2.70	1.03	1.07	1.90	1.30	.53	.77	.70
26	.73	1.27	1.23	1.20	1.33	3.20	2.70	.97	.93	1.90	1.33	.70	.77	.73
Macoupin	.73	.27	.37	.60	.53	1.00	------	1.00	.93	.50	.20	.07	.10	.10

TABLE No. 26.—*Summary of monthly average results of sanitary chemical analyses for each constituent, expressed in parts per million, arranged by sampling stations and months*—Continued

D. TOTAL NITROGEN

Sampling station	1921						1922							
	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
Summit	------	------	3.00	2.80	4.20	3.95	2.43	3.16	4.20	4.40	2.80	1.67	2.60	2.93
292	------	3.53	3.60	3.23	3.17	4.13	3.63	3.47	3.47	3.17	3.53	3.13	3.47	4.53
Des Plaines	------	2.03	2.13	4.55	6.40	8.27	5.00	5.00	4.60	3.15	2.77	2.67	2.23	2.33
286	------	3.27	3.60	3.50	4.67	5.17	3.53	3.27	3.47	2.93	2.40	3.33	3.70	4.53
Kankakee	------	.73	2.33	2.20	4.77	7.33	4.97	2.67	4.87	3.83	2.63	1.70	1.27	1.07
263	------	4.40	3.47	5.50	4.50	5.53	4.47	4.27	5.03	3.57	2.67	1.43	2.40	2.93
240	------	3.50	3.40	3.57	4.30	5.33	4.37	3.43	3.97	4.10	2.77	2.43	2.83	3.30
Fox	1.43	1.57	2.33	2.30	3.37	7.07	4.97	2.50	3.57	3.77	1.67	1.27	1.40	1.50
227	3.20	3.00	2.43	3.30	3.97	5.80	4.27	3.27	4.33	4.07	2.53	1.80	2.93	3.20
Vermilion	2.33	2.00	3.10	2.97	4.00	7.20	5.63	4.53	6.80	4.97	3.17	2.80	2.13	1.50
196	2.80	3.20	3.10	2.73	3.77	5.43	4.40	3.33	4.03	3.53	2.97	2.30	2.73	3.40
179	------	3.10	2.80	2.87	3.40	5.50	4.30	3.03	3.97	3.73	2.47	2.13	2.93	3.27
166	2.73	2.67	2.93	2.67	3.37	5.23	4.20	2.87	3.13	2.83	2.43	2.23	2.63	2.80
148	2.57	2.93	2.93	2.50	3.07	5.00	4.40	2.93	3.30	2.93	2.63	1.27	2.77	3.33
Mackinaw	2.37	3.13	2.83	2.27	2.73	5.60	5.20	3.03	5.20	2.83	3.30	2.20	1.80	1.60
Spoon	3.27	2.50	4.07	2.73	3.07	4.70	4.53	3.80	4.57	2.60	4.90	1.47	4.13	1.83
101	2.45	2.80	2.47	4.37	2.40	------	------	------	------	------	------	------	------	------
Sangamon	2.15	3.20	3.30	2.10	2.40	------	------	------	------	------	------	------	------	------
Crooked Creek	2.55	2.40	2.50	2.77	3.50	------	------	------	------	------	------	------	------	------
77	2.30	2.13	2.40	2.40	2.40	------	------	------	------	------	------	------	------	------
43	2.40	2.83	3.03	2.67	3.03	4.80	4.43	3.03	3.83	3.10	1.70	1.20	1.83	1.83
26	1.93	2.57	2.90	2.47	2.93	4.67	5.30	3.43	2.55	2.50	2.07	1.23	1.63	1.67
Macoupin	2.47	1.60	2.10	1.93	3.20	2.20	------	2.60	2.60	2.10	.80	.53	.50	1.30

E. OXYGEN CONSUMED

Sampling station	1921						1922							
	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
Summit	------	------	------	5.10	8.00	7.10	6.63	5.87	8.30	8.80	6.47	5.40	5.67	5.60
292	------	7.47	8.53	8.00	7.57	8.43	6.77	6.80	8.40	7.53	9.07	6.00	7.13	8.07
Des Plaines	------	7.67	10.20	11.60	9.90	8.53	6.37	8.57	12.40	10.00	10.07	12.07	12.33	11.07
286	------	7.83	8.60	8.50	9.03	8.07	6.33	8.60	9.73	9.57	7.37	6.93	6.80	7.40
Kankakee	------	5.23	7.27	5.27	8.10	6.70	5.80	15.87	10.13	14.60	9.67	7.40	6.00	5.67
263	------	7.97	8.33	9.13	8.20	7.80	10.20	8.53	10.30	13.00	8.27	7.57	7.40	6.13
240	------	5.45	8.30	9.07	7.93	8.97	7.10	7.13	9.03	14.73	8.80	7.67	8.33	8.30
Fox	7.57	9.20	10.93	8.73	9.73	8.37	7.13	7.47	12.00	11.53	8.13	6.40	6.73	6.67
227	6.57	7.10	7.40	7.67	8.30	8.73	7.23	8.40	11.07	13.07	8.47	7.27	7.73	7.27
Vermilion	7.13	7.10	8.60	14.33	6.70	4.97	5.50	9.53	12.73	13.47	3.67	4.00	5.33	6.13
196	5.83	5.37	6.90	7.40	8.77	7.73	6.33	7.70	9.93	9.60	7.60	4.93	6.60	8.40
179	------	4.75	5.57	5.40	6.07	6.13	6.03	5.83	9.07	9.33	7.47	5.80	4.60	4.80
166	5.10	5.22	6.00	5.33	6.33	5.00	5.00	4.93	6.57	7.20	6.67	5.73	5.27	6.07
148	6.17	5.47	6.57	5.53	5.77	4.87	8.10	5.20	7.47	7.87	7.60	6.73	6.60	6.47
Mackinaw	6.17	15.20	10.67	5.37	5.73	6.27	8.20	9.90	12.40	7.73	8.93	5.20	5.00	5.40
Spoon	11.20	10.60	17.47	9.53	8.50	7.67	7.77	10.63	16.27	7.20	15.80	6.20	14.33	5.27
101	6.40	5.37	6.20	7.80	6.60	------	------	------	------	------	------	------	------	------
Sangamon	5.85	11.47	13.13	5.57	6.80	------	------	------	------	------	------	------	------	------
Crooked Creek	6.95	12.47	21.87	10.27	11.90	------	------	------	------	------	------	------	------	------
77	5.70	12.27	7.33	5.57	7.00	------	------	------	------	------	------	------	------	------
43	6.43	6.07	11.20	6.87	6.60	6.27	7.30	8.53	11.73	6.40	6.00	5.00	7.33	5.27
26	5.87	5.77	8.67	5.80	6.67	6.30	14.08	15.67	10.80	7.00	6.60	4.27	6.27	4.47
Macoupin	9.10	10.10	12.33	9.33	9.67	7.20	------	7.60	13.40	15.40	6.07	4.27	5.00	5.20

Table No. 27.—*Summary of monthly average results of sanitary chemical analyses for each constituent, expressed in quantity units, arranged by sampling stations and months*

MONTHLY AVERAGE QUANTITY UNITS OF FREE AMMONIA IN THE ILLINOIS RIVER

[Observed values]

Month	Sampling station													
	Summit	292	286	263	240	227	196	179	166	148	101	77	43	26
1921														
July	......	......	......	......	......	15.85	17.75	......	15.45	12.26	8.56	7.67	1.25	1.61
August	......	14.64	13.81	16.43	18.40	16.12	17.55	18.30	16.69	14.70	8.55	8.40	1.23	.87
September	13.90	13.41	14.79	18.15	17.70	16.65	17.25	19.07	17.70	16.30	11.34	7.80	1.60	1.13
October	13.34	11.70	13.78	19.64	16.16	15.13	12.60	14.46	11.90	10.32	14.77	4.19	.47	1.59
November	13.57	12.15	11.99	17.90	14.42	15.40	12.53	14.94	13.36	12.47	9.96	3.63	9.70	7.91
December	11.01	8.67	9.06	15.57	13.21	15.99	12.00	17.96	17.43	16.88	......	......	13.48	11.25
1922														
January	11.06	11.63	10.44	18.62	14.82	17.66	16.93	17.55	16.06	14.42	......	......	18.34	17.82
February	13.41	10.31	6.06	14.39	17.50	13.29	16.36	18.35	15.49	15.19	......	......	17.52	20.55
March	18.55	9.61	9.78	14.58	16.06	14.74	16.82	22.04	19.17	16.80	......	......	19.45	16.90
April	14.16	9.67	9.80	18.92	12.58	14.43	16.91	21.95	17.46	12.96	......	......	17.86	9.12
May	14.82	17.85	15.59	19.30	13.96	16.49	14.75	15.14	8.73	5.66	......	......	6.73	5.30
June	11.53	17.15	13.86	14.16	12.26	15.12	14.83	15.42	9.41	6.29	......	......	1.62	1.65
July	13.89	17.66	16.77	18.23	20.07	18.86	19.58	19.76	16.45	12.06	......	......	2.09	1.63
August	13.80	14.74	15.88	15.46	17.12	17.30	18.48	18.89	14.44	11.41	......	......	1.57	.37
Averages														
Year	13.15	12.76	12.38	17.07	15.37	15.93	15.75	17.95	15.05	12.98	10.64	6.38	9.21	8.57
Summer	13.32	15.40	15.03	16.49	17.11	16.66	17.54	18.29	15.01	12.34	9.48	8.02	1.59	1.16
Winter	12.26	10.66	8.98	15.78	15.33	15.42	15.50	18.95	17.79	17.07	......	......	17.17	16.97
Summer transitional	13.88	14.62	14.68	19.47	14.51	15.81	13.68	14.80	10.32	7.99	......	......	3.00	3.44
Winter transitional	13.86	10.61	10.94	18.41	13.50	14.96	14.72	18.44	15.41	12.72	......	......	13.79	8.52

MONTHLY AVERAGE QUANTITY UNITS OF NITROGEN OXIDES IN THE ILLINOIS RIVER

1921														
July	......	......	......	......	......	0.00	0.00	......	0.00	0.00	3.75	3.62	10.70	9.06
August	......	0.00	0.00	0.64	0.00	.00	.00	0.00	.70	1.30	7.52	6.36	13.53	15.75
September	0.00	.00	.00	.00	.00	1.09	1.96	.82	1.53	.83	6.68	11.30	16.48	19.93
October	.00	.85	.26	1.06	2.44	3.69	6.68	7.68	10.24	10.71	15.18	16.50	20.07	19.08
November	4.17	3.81	11.02	20.96	32.09	30.26	29.18	27.06	24.15	21.55	16.60	21.72	23.79	24.47
December	6.33	6.94	22.57	46.54	54.30	69.42	87.12	89.30	88.89	87.44	......	......	112.22	109.13
1922														
January	2.49	3.07	5.83	17.75	19.32	27.56	28.77	43.49	48.24	53.56	......	......	78.08	79.11
February	.00	.00	1.67	4.92	4.63	10.00	10.18	8.89	10.59	10.79	......	......	22.56	21.44
March	.00	1.14	3.23	27.26	30.15	40.46	42.67	33.89	30.72	26.91	......	......	30.27	34.60
April	1.10	3.14	6.12	40.84	60.18	75.27	82.26	90.13	80.68	92.64	......	......	109.86	173.29
May	.00	.00	.00	1.96	7.70	6.80	18.18	18.08	27.61	35.18	......	......	67.34	70.49
June	.86	.00	1.20	2.01	2.74	1.64	3.31	5.25	6.11	9.01	......	......	13.78	18.48
July	.27	.00	.26	.00	.31	.00	.00	.00	.81	3.51	......	......	12.40	12.58
August	.00	.00	.00	.00	.00	.00	.00	.00	.71	1.31	......	......	8.47	8.91
Averages														
Year	1.25	1.58	4.35	13.61	17.82	22.18	26.69	27.05	28.27	29.62	9.94	11.94	45.69	49.29
Summer	.23	.00	.29	.53	.61	.46	.88	1.21	1.64	2.66	5.96	7.13	12.56	14.11
Winter	2.21	2.79	8.33	24.13	27.10	36.87	44.69	43.89	44.61	45.18	......	......	63.02	61.07
Summer transitional	.00	.42	.13	1.52	5.07	5.24	12.43	12.88	18.92	22.94	......	......	43.70	44.78
Winter transitional	2.64	3.48	8.57	30.90	46.14	52.76	55.72	58.60	56.92	57.10	......	......	96.82	98.88

TABLE No. 27.—*Summary of monthly average results of sanitary chemical analyses for each constituent, expressed in quantity units, arranged by sampling stations and months*—Continued

MONTHLY AVERAGE QUANTITY UNITS OF KJELDAHL NITROGEN IN THE ILLINOIS RIVER

Month	Sampling station													
	Summit	292	286	263	240	227	196	179	166	148	101	77	43	26
1921														
July	......	......	......	......	......	30.37	27.61	......	27.57	29.27	22.47	24.20	18.83	14.88
August	......	29.88	27.04	29.53	32.20	28.44	31.20	30.93	27.89	28.00	21.32	19.20	21.28	19.84
September	24.69	29.65	29.09	34.42	34.00	36.30	33.70	31.94	32.04	34.15	24.32	26.05	32.00	27.05
October	23.91	26.73	30.47	35.73	35.30	36.90	27.72	29.08	33.94	21.84	45.12	20.62	22.12	28.19
November	33.09	24.25	24.42	47.80	34.87	40.41	38.13	29.38	30.11	28.08	23.34	21.72	31.66	22.44
December	27.74	28.87	31.20	53.45	42.17	51.08	42.20	46.00	41.88	38.58	......	......	49.84	50.13
1922														
January	17.70	27.17	24.97	44.90	42.30	42.90	41.31	40.37	36.18	37.08	......	......	50.00	76.18
February	26.23	29.08	26.57	47.00	38.38	34.66	40.58	38.53	34.76	36.88	......	......	42.80	54.58
March	36.71	29.10	30.61	73.08	49.65	60.84	58.48	50.93	41.88	45.65	......	......	90.66	59.82
April	36.21	23.74	28.77	77.36	70.22	83.07	70.08	54.06	43.90	46.00	......	......	107.22	64.73
May	24.95	31.45	21.62	38.46	34.96	36.21	41.81	37.74	29.97	29.88	......	......	20.73	38.08
June	14.99	20.23	29.60	14.99	28.18	21.04	29.81	28.69	30.98	12.41	......	......	17.42	12.99
July	21.88	30.71	31.80	24.73	28.12	31.94	20.90	32.46	28.41	28.99	......	......	17.25	14.18
August	24.96	38.60	37.87	28.30	30.94	32.00	34.34	33.03	37.57	32.32	......	......	13.67	11.25
Averages														
Year	26.09	29.05	29.26	43.21	39.73	42.28	41.59	41.01	32.49	32.98	27.20	22.36	41.34	37.50
Summer	21.62	31.63	31.10	28.31	28.39	30.02	61.94	31.84	29.36	27.51	22.70	23.15	20.07	16.88
Winter	27.10	28.55	28.09	54.47	43.12	47.36	45.69	46.22	38.52	40.21	......	......	58.80	60.11
Summer transitional	24.43	29.09	26.04	37.10	35.13	36.58	34.76	33.40	26.90	25.53	......	......	21.42	29.44
Winter transitional	34.64	23.96	29.10	62.62	56.90	61.74	58.60	56.72	37.00	38.02	......	......	69.47	42.08

MONTHLY AVERAGE QUANTITY UNITS OF ORGANIC NITROGEN IN THE ILLINOIS RIVER

Month	Summit	292	286	263	240	227	196	179	166	148	101	77	43	26
1921														
July	......	......	......	......	......	14.52	9.80	......	12.12	16.01	13.91	16.33	17.89	13.27
August	......	15.22	13.28	23.10	13.80	12.32	13.65	12.36	11.26	13.30	12.77	10.80	20.05	19.47
September	10.70	16.22	14.30	16.27	16.39	19.62	16.45	12.87	15.34	17.88	12.98	18.25	30.40	25.92
October	10.67	15.03	16.69	16.09	20.14	21.77	15.12	14.60	12.04	11.22	20.26	16.43	21.65	18.60
November	19.51	12.07	22.43	20.99	20.18	24.92	25.60	14.44	16.73	15.86	13.28	18.10	21.96	21.53
December	16.73	20.20	22.15	36.88	28.96	35.04	31.20	28.04	24.15	21.68	......	......	36.08	35.88
1922														
January	6.65	15.54	14.53	26.18	27.78	25.24	24.38	22.82	20.10	22.06	......	......	31.79	58.00
February	12.82	18.77	18.91	33.21	20.88	21.37	24.32	20.28	16.27	18.36	......	......	26.28	34.04
March	23.16	19.48	20.83	58.50	33.57	46.10	41.66	37.92	22.41	29.86	......	......	71.20	40.92
April	22.05	14.67	12.98	58.44	66.64	68.64	62.15	62.11	26.44	35.04	......	......	60.40	45.60
May	10.43	13.90	6.08	19.16	21.10	19.72	27.00	22.60	21.24	23.80	......	......	13.99	23.39
June	3.46	12.18	15.72	.83	13.92	5.92	14.98	13.20	21.45	6.12	......	......	15.60	12.14
July	7.97	13.63	15.12	6.49	9.05	13.06	11.32	13.70	11.96	16.86	......	......	15.14	12.66
August	11.07	23.86	21.99	12.84	13.82	14.70	15.86	14.14	13.13	20.91	......	......	12.10	10.98
Averages														
Year	12.94	16.29	16.89	26.24	24.26	26.35	25.84	23.06	18.44	20.00	16.66	15.98	32.13	29.43
Summer	8.30	16.22	16.07	11.91	13.38	13.36	13.69	13.25	14.21	15.17	13.22	15.13	18.48	15.72
Winter	14.84	18.52	19.11	38.69	27.80	31.94	30.39	27.27	20.73	23.14	......	......	41.33	43.14
Summer transitional	10.55	14.46	11.39	17.62	20.62	20.74	21.09	18.60	16.64	17.54	......	......	17.82	26.00
Winter transitional	20.78	13.37	18.16	44.22	43.40	46.78	43.88	38.28	21.60	25.30	......	......	55.68	32.58

TABLE No. 27.—*Summary of monthly average results of sanitary chemical analyses for each constituent, expressed in quantity units, arranged by sampling stations and months*—Continued

MONTHLY AVERAGE QUANTITY UNITS OF TOTAL NITROGEN IN THE ILLINOIS RIVER

Month	Sampling station													
	Summit	292	286	263	240	227	196	179	166	148	101	77	43	26
1921														
July	......	......	......	......	......	30.37	37.61	......	27.57	29.27	26.22	27.83	29.52	22.92
August	......	29.86	27.94	40.17	32.26	25.44	31.20	30.66	28.59	29.30	28.84	25.58	34.81	35.59
September	24.69	29.63	28.09	34.42	34.00	37.29	35.66	32.76	34.57	34.98	31.09	37.44	48.48	46.98
October	23.91	27.58	30.73	26.78	37.74	40.59	24.40	35.74	34.15	32.25	60.31	37.21	42.19	29.57
November	37.25	28.03	45.44	68.55	66.66	70.67	67.31	56.44	54.26	49.59	39.94	42.44	55.45	58.61
December	34.07	35.81	52.77	98.99	96.47	120.45	130.22	135.30	130.47	126.00	......	......	161.76	150.25
1922														
January	20.19	30.24	30.80	62.58	61.62	70.46	82.08	83.86	84.42	90.44	......	......	128.02	168.20
February	26.23	29.09	27.24	52.52	42.01	44.66	50.76	47.42	45.35	47.34	......	......	68.39	76.03
March	25.71	30.24	25.84	100.29	79.80	101.32	101.15	93.85	72.30	77.86	......	......	129.92	94.12
April	37.31	30.88	29.89	118.29	130.40	158.34	161.22	174.19	123.86	140.64	......	......	277.14	288.69
May	24.95	31.45	21.67	40.44	42.66	43.01	50.99	55.82	57.58	64.70	......	......	88.06	189.15
June	15.65	29.33	30.80	17.60	28.92	22.69	32.12	33.87	26.97	21.42	......	......	31.20	32.47
July	22.19	30.71	32.15	24.72	29.43	31.94	30.90	32.46	29.32	32.41	......	......	29.65	26.73
August	24.96	28.60	37.87	28.30	30.94	32.00	24.34	23.03	28.28	33.63	......	......	22.14	23.28
Averages														
Year	27.34	30.63	32.61	56.92	57.55	64.46	68.29	68.06	61.76	62.60	37.24	34.30	90.03	86.79
Summer	21.65	31.63	31.39	29.92	31.10	30.47	22.14	32.76	30.87	30.17	28.69	30.25	32.62	30.99
Winter	29.30	31.34	36.42	78.60	70.23	84.23	95.56	90.11	83.13	85.38	......	......	121.52	121.17
Summer transitional	24.43	29.52	26.18	38.61	40.20	41.80	47.20	46.26	45.98	48.48	......	......	65.12	74.22
Winter transitional	37.28	27.46	37.06	93.52	103.03	114.50	114.22	115.32	93.92	95.11	......	......	166.20	170.96

MONTHLY AVERAGE QUANTITY UNITS OF OXYGEN CONSUMED IN THE ILLINIOS RIVER

1921														
July	......	......	......	......	......	65.20	57.48	......	51.51	62.93	68.46	62.97	79.09	72.79
August	......	63.20	60.62	72.77	80.14	67.31	52.26	46.98	52.09	54.70	55.31	147.24	74.66	71.55
September	......	70.20	71.10	82.63	83.00	80.66	79.35	65.17	70.50	81.75	78.12	114.35	179.20	140.45
October	43.55	68.32	74.63	95.87	98.14	94.34	93.24	69.12	66.27	71.34	107.64	90.99	108.55	98.22
November	70.96	67.15	88.04	125.46	122.92	147.74	156.96	100.76	101.91	93.47	112.98	126.70	120.78	122.73
December	61.36	73.09	83.93	139.62	162.36	191.19	185.52	150.90	124.50	122.72	......	......	211.30	214.83
1922														
January	55.09	56.26	55.07	142.80	100.11	119.30	115.21	117.59	100.50	166.96	......	......	710.97	411.07
February	49.19	56.98	71.64	104.92	89.13	115.09	117.04	90.96	77.89	83.72	......	......	186.51	344.31
March	72.54	73.42	95.16	202.96	199.89	259.04	249.24	214.96	158.70	175.55	......	......	430.49	491.78
April	74.62	63.85	100.67	431.60	500.82	509.73	438.72	435.71	339.84	377.70	......	......	572.16	628.40
May	57.65	80.81	65.50	125.70	135.52	143.99	153.52	168.82	157.41	166.96	......	......	341.96	349.80
June	50.60	50.22	64.10	92.87	91.27	91.60	70.99	92.22	94.55	114.41	......	......	130.09	112.73
July	50.18	63.10	59.09	76.22	86.63	84.26	74.71	52.53	60.61	77.22	......	......	118.01	102.20
August	47.71	68.76	61.86	59.22	79.29	72.70	84.84	48.48	61.31	65.35	......	......	63.77	54.53
Averages														
Year	57.90	66.51	74.23	139.99	145.57	159.14	151.61	133.93	118.02	134.76	84.49	109.60	222.83	246.70
Summer	49.80	64.39	62.35	76.67	78.07	76.96	69.96	61.08	63.14	76.06	67.30	110.19	124.12	109.04
Winter	59.59	64.94	76.45	147.88	137.80	171.15	168.78	143.50	115.40	137.21	......	......	259.80	337.31
Summer transitional	60.60	74.56	70.06	110.78	115.83	119.16	123.38	118.97	112.82	129.15	......	......	225.22	221.01
Winter transitional	72.79	65.50	94.36	278.53	311.87	328.74	297.85	268.24	220.88	235.62	......	......	346.47	380.86

Table No. 27.—*Summary of monthly average results of sanitary chemical analyses for each constituent, expressed in quantity units, arranged by sampling stations and months*—Continued

MONTHLY AVERAGE QUANTITY UNITS OF FREE AMMONIA IN TRIBUTARIES OF THE ILLINOIS RIVER

[Observed values]

Month	Des Plaines	Kankakee	Fox	Vermilion	Mackinaw	Spoon	Sangamon	Crooked Creek	Macoupin Creek
1921									
July			0.04	0.01	0.03	0.09	0.45	0.05	0.01
August	0.01	0.07	.02	.00	.07	.08	1.02	.07	.03
September	.08	.00	.10	.12	.08	.07	2.17	.98	.07
October	.14	.06	.05	.00	.09	.01	.30	.02	.09
November	.27	.15	.43	.10	.11	.05	1.64	.06	.18
December	.47	.56	.61	.51	.31	.23			.17
1922									
January	.48	.49	.97	.24	.13	.34			
February	.26	2.05	.57	.28	.37	.87			.08
March	.56	1.84	1.22	.69	.51	.94			.67
April	.32	3.33	.91	.39	1.60	1.12			1.13
May	.09	.38	.15	.08	.08	.30			.08
June	.04	.33	.08	.03	.02	.05			.00
July	.02	.24	.11	.05	.01	.17			.09
August	.01	.09	.08	.00	.01	.02			.00
Averages									
Year	.21	.84	.46	.21	.22	.36	1.08	.24	.10
Summer	.02	.15	.08	.06	.05	.08	1.21	.37	.03
Winter	.41	1.24	.92	.41	.33	.64			.31
Summer transitional	.12	.48	.10	.04	.04	.10			.03
Winter transitional	.30	1.74	.67	.34	.56	.60			.65

MONTHLY AVERAGE QUANTITY UNITS OF NITROGEN OXIDES IN TRIBUTARIES OF ILLINOIS RIVER

Month	Des Plaines	Kankakee	Fox	Vermilion	Mackinaw	Spoon	Sangamon	Crooked Creek	Macoupin Creek
1921									
July			0.01	0.00	0.04	0.16	0.26	0.09	0.08
August	0.00	0.05	.01	.00	.09	.25	.53	.30	.06
September	.00	1.23	.10	.28	.97	.69	1.18	.60	.09
October	.35	1.40	1.61	.33	.42	.42	1.44	.33	.05
November	4.42	17.58	4.98	2.65	1.42	.64	4.31	.41	.41
December	10.09	34.42	19.60	7.26	4.84	2.77			.83
1922									
January	1.68	17.99	7.46	1.82	2.13	1.99			
February	.19	5.15	1.41	2.27	.08	2.45			.41
March	2.14	25.76	4.63	12.47	5.31	2.66			2.13
April	2.48	39.81	8.08	12.52	6.80	6.16			2.80
May	.18	6.71	1.18	2.94	1.06	1.85			.07
June	.01	1.10	.20	.34	.43	.53			.01
July	.01	.34	.11	.08	.09	.80			.00
August	.00	.00	.01	.00	.01	.00			.09
Averages									
Year	1.80	12.63	4.11	3.50	2.07	1.76	1.84	.35	.71
Summer	.03	.54	.07	.11	.27	.42	.86	.33	.04
Winter	3.53	20.85	8.28	5.94	3.25	2.47			1.46
Summer transitional	.28	4.10	1.40	1.18	1.06	1.14			.08
Winter transitional	3.45	28.70	6.52	7.58	4.11	3.40			1.69

TABLE No. 27.—*Summary of monthly average results of sanitary chemical analyses for each constituent, expressed in quantity units, arranged by sampling stations and months*—Continued

MONTHLY AVERAGE QUANTITY UNITS OF ORGANIC NITROGEN IN TRIBUTARIES OF ILLINOIS RIVER

[Observed values]

Month	Des Plaines	Kankakee	Fox	Vermilion	Des Plaines and Kankakee	Des Plaines, Kankakee, and Fox	Des Plaines, Kankakee, Fox, and Vermilion
1921							
July	------	------	0.28	0.00	------	0.28	0.28
August	0.01	0.40	.36	.00	0.41	.77	.77
September	.06	1.64	1.65	.55	1.70	3.35	3.90
October	.41	.89	2.16	.22	1.30	3.46	3.68
November	1.65	5.22	1.39	1.33	6.87	8.26	9.59
December	2.85	7.55	5.12	1.43	10.40	15.52	16.95
1922							
January	.31	5.65	2.80	.44	5.96	8.76	9.20
February	.17	3.10	.89	.06	3.27	4.16	4.22
March	2.07	17.20	5.37	4.35	19.27	24.64	28.99
April	2.24	31.97	8.20	9.35	34.21	42.41	51.76
May	.43	5.98	1.14	.33	6.41	7.55	7.88
June	.12	1.84	.52	.16	1.96	2.48	2.64
July	.07	.71	.53	.08	.78	1.31	1.39
August	.07	.67	.45	.00	.74	1.19	1.19
Averages							
Year	.82	6.88	2.58	1.66	7.70	10.28	11.94
Summer	.06	1.06	.64	.13	1.12	1.57	1.70
Winter	1.35	8.38	3.54	1.72	------	------	------
Summer transitional	.42	3.44	1.65	.28	3.86	5.50	5.78
Winter transitional	1.64	18.64	5.06	5.64	20.28	25.34	30.98

MONTHLY AVERAGE QUANTITY UNITS OF KJELDAHL NITROGEN IN TRIBUTARIES OF ILLINOIS RIVER

[Observed values]

Month	Des Plaines	Kankakee	Fox	Vermilion	Mackinaw	Spoon	Sangamon	Crooked Creek	Macoupin Creek
1921									
July	------	------	0.23	0.01	0.21	0.48	1.34	0.40	0.15
August	0.02	0.47	.38	.00	.64	.74	3.00	1.08	.80
September	.09	1.64	1.75	.64	1.30	2.30	4.73	3.72	.40
October	.55	.97	2.21	.22	.24	.40	1.31	.55	.11
November	1.22	5.47	2.32	1.43	.82	.30	4.31	.38	1.25
December	3.22	8.13	5.73	1.94	1.74	1.08	------	------	1.00
1922									
January	.79	6.17	3.77	.08	1.19	1.48	------	------	------
February	.42	5.15	1.46	.94	1.22	2.53	------	------	.65
March	2.62	19.04	6.89	4.94	4.55	4.81	------	------	5.62
April	2.86	25.30	9.11	9.96	3.72	1.12	------	------	2.97
May	.33	6.86	1.20	.41	.96	4.68	------	------	.21
June	.16	2.17	.58	.19	.28	.20	------	------	.04
July	.09	.95	.04	.11	.12	2.35	------	------	.01
August	.08	.76	.48	.00	.08	.19	------	------	.08
Averages									
Year	1.03	7.72	3.02	1.70	1.37	1.89	2.95	1.23	1.08
Summer	.09	1.20	.70	.16	.46	1.21	3.05	1.73	.15
Winter	1.76	9.62	4.46	2.13	2.20	2.46	------	------	2.42
Summer transitional	.54	2.92	1.75	.32	.60	2.56	------	------	.16
Winter transitional	1.94	20.36	5.72	5.08	2.27	.96	------	------	.75

TABLE No. 27.—*Summary of monthly average results of sanitary chemical analyses for each constituent, expressed in quantity units, arranged by sampling stations and months*—Continued

MONTHLY AVERAGE QUANTITY UNITS OF TOTAL NITROGEN IN TRIBUTARIES OF ILLINOIS RIVER

Month	Des Plaines	Kankakee	Fox	Vermilion	Mackinaw	Spoon	Sangamon	Crooked Creek	Macoupin Creek
1921									
July	--------	--------	0.32	0.01	0.25	0.64	1.60	0.40	0.21
August	0.02	0.52	.39	.00	.73	.99	3.62	1.36	.36
September	.09	2.67	1.88	.90	2.36	2.98	5.91	4.32	.49
October	.90	2.46	3.82	.55	.67	.91	2.75	.85	.16
November	5.74	23.05	7.30	4.08	2.24	1.28	8.62	.79	1.60
December	12.31	42.65	24.38	9.14	6.38	3.80	--------	--------	1.63
1922									
January	2.47	24.16	11.28	2.50	3.32	3.47	--------	--------	--------
February	.61	10.30	2.87	3.21	2.27	4.98	--------	--------	1.06
March	4.76	44.80	11.52	17.41	9.86	7.49	--------	--------	8.75
April	5.04	75.11	17.17	22.46	10.83	7.28	--------	--------	11.77
May	.70	13.57	2.47	2.45	2.64	6.46	--------	--------	.28
June	.17	3.27	.78	.53	.71	.73	--------	--------	.05
July	.10	1.29	.75	.19	.22	4.24	--------	--------	.01
August	.08	.76	.49	.00	.09	.19	--------	--------	.02
Averages									
Year	2.83	20.35	7.13	5.29	3.44	3.65	4.50	1.57	2.37
Summer	.09	1.74	.77	.27	.74	1.63	3.71	2.06	.19
Winter	5.29	30.45	12.74	8.07	5.45	4.94	--------	--------	3.88
Summer transitional	.90	8.02	3.15	1.50	1.66	3.60	--------	--------	.22
Winter transitional	5.34	49.08	12.24	13.27	6.38	4.24	--------	--------	6.73

MONTHLY AVERAGE QUANTITY UNITS OF OXYGEN CONSUMED IN TRIBUTARIES OF ILLINOIS RIVER

1921									
July	--------	--------	1.70	0.04	0.64	2.18	4.35	1.33	0.81
August	0.08	3.70	2.28	.01	3.59	4.21	13.00	7.05	2.28
September	.45	8.94	8.82	2.49	8.86	12.84	25.89	32.91	2.85
October	2.30	5.90	14.48	2.68	1.58	3.16	7.31	3.28	.79
November	8.87	39.24	21.08	6.83	4.71	3.39	24.44	3.72	7.42
December	13.72	88.89	30.00	6.22	7.15	6.20	--------	--------	5.98
1922									
January	3.14	28.19	16.11	2.44	5.13	5.94	--------	--------	--------
February	1.07	61.43	8.58	6.75	6.12	13.95	--------	--------	3.11
March	12.82	93.19	38.83	32.59	23.51	26.72	--------	--------	45.12
April	15.98	286.31	52.53	60.88	28.72	20.15	--------	--------	86.32
May	2.53	49.90	12.04	2.84	7.14	20.90	--------	--------	2.09
June	.80	14.23	3.97	.75	1.67	3.08	--------	--------	.39
July	.49	6.13	3.57	.47	.61	14.66	--------	--------	.13
August	.36	4.04	1.98	.01	.28	.54	--------	--------	.10
Averages									
Year	5.21	53.08	17.67	10.41	7.96	10.96	15.00	9.06	14.00
Summer	.44	7.41	3.72	.44	2.61	6.25	14.41	13.76	1.09
Winter	7.69	55.43	23.38	12.00	10.48	13.20	--------	--------	18.07
Summer transitional	2.42	27.90	13.26	2.76	4.36	12.03	--------	--------	1.44
Winter transitional	12.42	162.77	36.80	33.86	16.72	11.77	--------	--------	46.87

For the purpose of illustrating the changes taking place in the organic chemical constituents contributed by the main drainage canal during the time of flow from Lockport to Peoria, the chemical analyses of the main stream from station 292 to station 166, inclusive, expressed in quantity units, have been corrected by subtracting from the observed amounts of the various constituents the quantities added by the principal tributaries to this section of the river above the respective sampling stations. These corrected results are presented in Table No. 28. In deriving these corrected values no account has been taken of the relatively small amounts of constituents contributed by sources other than the principal tributaries, such as direct inflow and sewered population along the stream channel. Likewise no allowance was made for possible internal changes in these organic constituents contributed by such tributaries during their progress past the successive sampling stations of the main stream. The calculated quantity units contributed by tributaries as given in Table No. 27 were the values applied to the observed results to derive the corrected quantity unit figures for the main channel.

TABLE No. 28.—*Summary of monthly average results of sanitary chemical analyses for each constituent of the upper Illinois River, expressed in quantity units, with contributions by tributaries deducted*

MONTHLY AVERAGE QUANTITY UNITS OF FREE AMMONIA IN THE ILLINOIS RIVER, WITH DEDUCTIONS CONTRIBUTED BY TRIBUTARIES

Month	Sampling station							
	292	285	263	240	227	196	179	166
1921								
August	14.64	13.80	16.35	18.32	16.02	17.45	18.20	15.53
September	13.41	14.76	18.12	17.67	16.56	17.00	18.82	17.45
October	11.70	13.64	19.42	14.94	14.86	12.23	14.19	11.63
November	12.15	11.72	17.48	14.00	14.64	11.58	13.99	12.41
December	8.67	8.68	14.62	12.26	14.43	9.93	15.89	15.36
1922								
January	11.63	9.96	17.65	13.55	15.72	14.75	15.37	13.90
February	10.31	6.41	12.09	15.20	10.42	13.11	16.10	15.34
March	9.61	9.23	12.14	13.69	10.83	12.82	17.54	14.67
April	9.67	9.57	15.27	8.96	9.67	11.76	16.80	12.31
May	17.55	15.80	18.33	12.89	15.87	13.55	13.94	7.53
June	17.15	13.84	13.79	11.89	14.69	14.37	14.96	8.95
July	17.08	16.75	17.97	19.81	18.49	19.18	19.36	16.05
August	14.74	15.87	15.36	17.02	17.17	18.85	18.76	14.31
Averages								
Year	12.76	12.16	16.02	14.32	14.42	14.62	16.23	13.33
Summer	15.40	15.00	16.22	16.94	16.86	17.27	18.02	14.66
Winter	10.05	8.57	14.13	13.68	12.85	12.53	15.97	14.83
Summer transitional	14.62	14.57	16.85	13.92	15.13	12.94	14.06	9.58
Winter transitional	10.61	10.94	16.38	11.46	12.26	11.67	15.40	12.36

MONTHLY AVERAGE QUANTITY UNITS OF NITROGEN OXIDES IN THE ILLINOIS RIVER, WITH DEDUCTIONS CONTRIBUTED BY TRIBUTARIES

1921								
August	0.00	0.00	0.59	−0.05	−0.06	−0.08	−0.06	0.64
September	.00	.00	−1.23	−1.23	−.24	.37	−.77	−.06
October	.85	−.09	−.79	.00	.24	2.90	3.90	6.46
November	3.81	6.60	−1.04	10.09	3.28	−.45	−2.57	−5.48
December	6.94	12.48	2.03	9.79	5.31	15.81	17.99	17.68
1922								
January	3.07	4.15	−1.89	−.35	.43	9.82	14.54	19.29
February	.00	1.48	−.42	−.71	3.25	1.16	−.13	1.57
March	1.14	1.09	−.64	2.25	7.95	−2.33	−11.11	−14.26
April	3.14	3.64	−1.45	17.89	24.92	19.39	27.26	26.31
May	.00	−.18	−4.91	.81	−1.27	8.07	7.97	17.80
June	.00	1.19	.90	1.63	.33	1.66	3.60	4.46
July	.00	.25	−.35	−.04	−.46	−.54	−.54	.27
August	.00	.00	.00	.00	−.01	−.01	−.01	.70
Averages								
Year	1.58	2.56	−.82	3.39	3.64	4.65	5.01	6.24
Summer	.00	.29	−.02	.06	−.06	.28	.44	1.20
Winter	2.79	4.80	−.23	2.75	4.24	6.12	5.32	6.04
Summer transitional	.42	−.14	−2.85	.70	−.52	5.48	5.94	11.98
Winter transitional	3.48	5.12	−1.24	13.99	14.10	9.47	12.34	10.66

TABLE No. 28.—*Summary of monthly average results of sanitary chemical analyses for each constituent of the upper Illinois River, expressed in quantity units, with contributions by tributaries deducted*—Continued

MONTHLY AVERAGE QUANTITY UNITS OF KJELDAHL NITROGEN IN THE ILLINOIS RIVER, WITH DEDUCTIONS CONTRIBUTED BY TRIBUTARIES

Month	Sampling station							
	293	285	263	240	237	196	170	166
1921								
August	29.86	27.02	28.04	31.71	27.57	30.33	28.79	27.02
September	29.69	29.00	32.69	32.37	32.79	29.65	27.79	28.89
October	26.73	29.92	34.21	32.78	32.17	23.77	25.11	19.99
November	24.23	33.10	41.10	27.78	31.20	27.89	18.84	19.57
December	28.87	27.98	41.10	30.82	32.95	24.18	26.98	22.56
1922								
January	27.17	24.18	37.84	35.24	32.17	29.90	28.96	24.77
February	29.08	25.15	42.03	32.51	27.63	32.61	30.55	26.79
March	29.10	27.90	51.37	27.90	32.29	34.99	28.47	8.09
April	23.74	21.21	39.50	41.36	36.10	22.15	27.15	−13.01
May	31.45	31.10	31.68	27.58	27.84	22.73	28.68	20.69
June	29.28	29.44	12.66	23.85	18.13	26.71	25.52	27.76
July	30.71	31.80	23.66	28.06	30.26	30.11	31.67	26.02
August	33.60	37.79	27.46	30.10	30.68	32.02	31.71	26.25
Averages								
Year	29.06	28.22	34.56	30.98	30.50	28.03	27.45	19.93
Summer	31.63	31.01	27.11	29.20	27.89	29.80	29.30	27.31
Winter	28.55	26.33	43.09	31.74	31.51	27.92	28.24	20.86
Summer transitional	29.09	25.51	32.64	30.08	30.26	28.26	26.86	20.44
Winter transitional	22.98	27.16	40.30	34.57	[illegible]70	24.87	23.00	3.26

MONTHLY AVERAGE QUANTITY UNITS OF ORGANIC NITROGEN IN THE ILLINOIS RIVER, WITH DEDUCTIONS CONTRIBUTED BY TRIBUTARIES

1921								
August	15.23	13.23	22.69	13.39	11.56	12.88	11.59	10.40
September	16.23	14.24	14.57	14.60	16.24	12.55	8.97	11.44
October	15.08	16.28	14.70	18.84	18.31	11.44	10.92	8.26
November	12.67	21.36	23.62	13.78	16.66	16.01	4.85	7.16
December	20.30	19.30	26.48	18.56	19.52	14.25	11.09	7.20
1922								
January	15.84	14.23	20.19	21.79	16.45	15.15	13.59	10.87
February	18.77	18.74	28.94	17.61	17.21	19.50	15.46	11.45
March	10.49	18.76	30.23	14.30	21.46	12.67	8.98	−6.58
April	14.67	11.64	24.23	22.43	26.23	10.39	10.25	−25.23
May	13.90	8.60	12.75	14.69	12.17	19.18	14.72	13.26
June	12.18	15.69	−1.13	11.96	3.44	12.34	10.56	18.61
July	13.62	15.66	8.71	8.27	11.77	9.93	12.31	10.57
August	23.86	21.92	13.10	13.08	13.51	14.67	12.95	11.94
Averages								
Year	16.29	16.06	18.84	16.06	16.08	14.01	11.22	6.60
Summer	16.22	16.01	10.79	13.26	11.30	12.47	11.28	12.65
Winter	18.50	17.76	28.96	18.06	18.66	15.39	12.27	5.73
Summer transitional	14.48	10.94	13.77	16.76	15.24	15.31	12.82	10.86
Winter transitional	13.37	16.81	23.92	23.10	21.44	13.20	7.92	−9.06

TABLE No. 28.—*Summary of monthly average results of sanitary chemical analyses for each constituent of the upper Illinois River, expressed in quantity units, with contributions by tributaries deducted*—Continued

MONTHLY AVERAGE QUANTITY UNITS OF TOTAL NITROGEN IN THE ILLINOIS RIVER, WITH DEDUCTIONS CONTRIBUTED BY TRIBUTARIES

Month	Sampling station							
	293	286	263	260	227	196	179	160
1921								
August	29.96	27.02	30.63	31.96	27.01	30.27	29.73	27.06
September	29.68	29.00	31.46	31.04	32.55	29.93	27.03	29.03
October	27.38	29.83	33.43	34.36	33.41	26.07	30.01	26.46
November	26.03	30.70	40.06	37.57	34.86	37.14	16.27	14.00
December	35.81	40.46	43.13	40.61	39.36	33.90	44.97	40.14
1922								
January	30.24	28.33	35.96	34.90	32.00	39.72	48.80	44.06
February	29.68	26.62	41.61	33.10	30.88	33.77	30.43	28.36
March	30.24	29.08	50.73	30.34	40.24	22.66	15.36	−6.19
April	26.88	24.85	28.06	50.25	61.02	41.54	54.41	13.80
May	31.45	29.92	26.17	28.30	26.27	40.60	36.66	28.30
June	29.33	30.63	13.86	25.46	18.46	28.37	30.12	32.22
July	30.71	33.06	23.33	28.04	29.80	28.57	31.13	29.09
August	28.90	37.79	27.46	30.10	30.67	33.61	31.70	26.96
Averages								
Year	30.63	30.77	33.74	34.37	34.14	32.68	32.46	26.17
Summer	31.63	31.30	27.09	29.26	29.74	30.03	28.74	28.51
Winter	31.34	31.13	42.86	34.49	35.75	34.04	33.36	26.80
Summer transitional	29.53	26.36	28.30	31.26	30.84	33.74	32.63	32.42
Winter transitional	27.46	32.26	39.66	46.56	47.80	34.34	36.34	13.94

MONTHLY AVERAGE QUANTITY UNITS OF OXYGEN CONSUMED IN THE ILLINOIS RIVER, WITH DEDUCTIONS CONTRIBUTED BY TRIBUTARIES

1921								
August	62.20	60.54	68.90	46.36	61.25	46.29	40.91	46.02
September	70.20	70.65	73.24	73.61	62.45	58.68	44.47	59.10
October	66.32	72.33	87.67	87.94	71.96	67.86	42.76	42.86
November	67.15	79.17	77.35	74.81	78.55	80.96	24.74	25.99
December	73.60	70.21	87.01	109.75	108.58	98.60	61.97	35.67
1922								
January	56.26	51.93	111.47	68.78	71.86	65.33	67.71	80.63
February	56.98	70.57	42.43	36.63	44.90	80.21	17.43	.06
March	73.42	82.34	96.97	92.56	114.20	71.84	87.82	−18.73
April	62.85	94.69	129.31	198.53	154.91	28.62	30.01	−75.96
May	90.81	62.97	73.27	82.09	79.52	86.21	101.81	90.10
June	56.22	63.30	77.84	76.34	73.60	51.24	72.47	74.80
July	63.10	56.60	69.60	80.01	74.07	64.05	41.87	46.98
August	68.76	61.50	54.82	74.89	66.32	78.46	42.09	54.92
Averages								
Year	66.51	69.42	81.75	87.33	83.23	65.29	47.60	81.70
Summer	64.30	62.92	68.90	70.22	67.34	60.74	48.36	55.16
Winter	64.94	68.76	85.97	74.69	84.66	68.25	45.08	16.91
Summer transitional	74.56	67.65	80.47	86.52	75.59	72.05	72.64	66.48
Winter transitional	65.56	81.93	103.33	136.67	116.73	51.99	22.38	−24.98

For convenience, the yearly and seasonal averages of the sanitary chemical analyses, expressed in parts per million, are summarized in Table No. 29. Likewise, the yearly and seasonal averages, both of observed and of corrected values expressed in terms of quantity units of the various constituents, are presented in Table No. 30.

TABLE No. 20.—*Yearly and seasonal average sanitary chemical analyses of Illinois River and tributaries*

[Figures in parts per million]

	Summit	292	Des Plaines	286	Kankakee	263	240	Fox	227
Free ammonia:									
Year	1.58	1.47	0.63	1.38	0.16	1.26	1.17	0.23	1.09
Summer	1.53	1.77	.54	1.77	.13	1.64	1.70	.13	1.59
Winter	1.44	1.18	.96	.27	.20	1.08	.99	.30	.85
Summer transitional	1.80	1.60	.54	1.65	.12	1.57	1.16	.05	1.10
Winter transitional	1.60	1.21	.25	1.10	.10	.87	.65	.20	.63
Organic nitrogen:									
Year	1.30	1.99	1.60	1.36	1.14	1.65	1.65	1.26	1.47
Summer	.97	1.88	1.67	1.88	.90	1.23	1.22	1.36	1.30
Winter	1.73	2.17	1.45	2.05	1.29	2.39	1.73	1.28	1.67
Summer transitional	1.21	1.53	1.90	1.28	.95	1.38	1.64	1.06	1.48
Winter transitional	2.40	1.56	1.29	1.83	1.37	1.86	1.63	1.34	1.58
Kjeldahl nitrogen:									
Year	2.83	2.86	2.23	2.24	1.30	2.93	2.73	1.48	2.56
Summer	2.50	2.65	2.21	2.65	1.03	2.87	3.02	1.49	2.89
Winter	3.16	3.35	2.40	2.02	1.63	3.42	2.73	1.67	2.52
Summer transitional	2.80	3.23	2.44	2.93	1.10	2.96	2.80	1.10	2.58
Winter transitional	4.00	2.77	1.54	2.93	1.47	2.73	2.28	1.54	2.20
Nitrogen oxides:									
Year	.14	.18	1.88	.44	2.06	.72	.92	1.50	.99
Summer	.02	.00	.09	.03	.39	.08	.05	.12	.04
Winter	.38	.23	3.32	.84	3.44	1.41	1.56	2.96	1.82
Summer transitional	.00	.05	1.22	.02	1.32	.12	.37	.88	.35
Winter transitional	.30	.40	3.24	.67	2.83	1.30	1.93	2.03	1.82
Total nitrogen:									
Year	3.17	3.54	4.10	2.68	3.30	3.65	3.64	2.96	3.55
Summer	2.53	2.65	2.30	2.68	1.42	2.92	3.07	1.58	2.93
Winter	3.42	3.68	5.72	2.86	4.96	4.83	4.28	4.63	4.34
Summer transitional	2.80	3.28	3.66	2.95	2.42	3.08	3.17	1.98	2.91
Winter transitional	4.30	3.17	4.78	2.80	4.30	4.03	4.20	3.57	4.02
Oxygen consumed:									
Year	6.06	7.69	10.28	8.11	8.84	8.70	8.85	9.00	8.55
Summer	5.66	7.44	10.67	7.45	6.31	7.54	7.59	7.82	7.27
Winter	6.95	7.60	9.04	8.18	9.63	9.18	8.28	8.74	8.86
Summer transitional	5.78	8.54	10.84	7.58	7.47	8.70	8.94	8.43	8.07
Winter transitional	8.40	7.55	9.95	9.43	11.35	10.60	11.23	10.63	10.68

	Vermilion	196	179	166	148	Mackinaw	Spoon	43	26	Macoupin
Free ammonia:										
Year	0.27	1.61	1.69	0.91	0.77	0.18	0.19	0.21	0.26	0.15
Summer	.48	1.62	1.61	1.26	1.11	.16	.20	.10	.07	.16
Winter	.40	.70	.96	.88	.83	.34	.55	.50	.60	.30
Summer transitional	.06	.86	.90	.65	.52	.06	.09	.06	.10	.05
Winter transitional	.12	.54	.68	.60	.52	.20	.30	.36	.26	.22
Organic nitrogen:										
Year	1.19	1.35	1.18	1.03	1.11	1.24	1.67	1.13	1.08	1.07
Summer	1.22	1.23	1.15	1.21	1.38	1.48	1.96	1.26	1.06	1.03
Winter	1.18	1.45	1.31	.90	1.10	1.65	1.47	1.33	1.45	1.29
Summer transitional	.81	1.27	1.07	.92	.92	.95	2.39	.82	.90	.91
Winter transitional	1.08	1.39	1.10	.80	.84	.80	.64	1.10	.84	1.41
Kjeldahl nitrogen:										
Year	1.46	2.36	2.27	1.94	1.88	1.42	1.96	1.14	1.36	1.22
Summer	1.70	2.85	2.75	2.57	2.49	1.64	2.16	1.36	1.13	1.18
Winter	1.58	2.37	2.24	1.87	1.93	1.99	2.02	1.92	2.04	1.49
Summer transitional	.86	2.13	1.97	1.57	1.44	1.00	2.48	.90	1.00	.96
Winter transitional	1.50	1.93	1.78	1.40	1.36	1.00	.94	1.46	1.10	1.63
Nitrogen oxides:										
Year	2.61	1.12	1.10	1.16	1.21	1.86	1.56	1.41	1.42	.49
Summer	.61	.07	.08	.12	.19	.09	.72	.82	.90	.27
Winter	4.46	2.08	1.97	1.99	1.99	2.94	2.38	2.05	1.95	.98
Summer transitional	2.20	.72	.70	.98	1.13	1.78	1.34	1.28	1.27	.40
Winter transitional	2.68	1.72	1.78	1.70	1.62	1.78	1.90	1.60	1.62	.53
Total nitrogen:										
Year	4.07	3.48	3.37	3.10	3.09	3.27	3.54	2.55	2.78	1.71
Summer	2.31	2.92	2.84	2.69	2.68	2.33	2.88	2.19	2.08	1.42
Winter	6.04	4.30	4.20	3.86	3.91	4.95	4.40	3.95	3.99	2.47
Summer transitional	3.06	2.85	2.67	2.55	2.57	2.78	3.82	2.18	2.27	1.36
Winter transitional	4.48	3.65	3.56	3.10	3.00	2.78	2.84	3.06	2.72	2.15
Oxygen consumed:										
Year	7.91	7.66	6.34	5.87	6.59	7.57	10.55	7.42	8.05	8.68
Summer	6.38	6.34	5.10	5.57	6.38	7.94	10.84	6.88	5.89	7.67
Winter	8.18	7.92	6.77	5.45	6.41	9.19	10.50	8.46	11.70	9.40
Summer transitional	9.00	7.50	6.44	6.00	6.36	7.15	12.68	6.74	6.20	7.70
Winter transitional	10.08	9.18	7.70	6.76	6.83	6.00	7.85	6.50	6.84	12.57

◀◀◀

TABLE No. 30.—*Yearly and seasonal average sanitary chemical analyses of Illinois River and tributaries*

[Results in quantity units; parts per million × thousands of second-feet discharge]

	Summit	292	Des Plaines	286	Kankakee	263	240	Fox	227	Vermilion	196	179	166	148	Mackinaw	Spoon	101	Sangamon	Crooked Creek	77	48	20	Macoupin
FREE AMMONIA																							
Observed values:																							
Year	13.15	12.76	0.21	12.38	0.94	17.07	15.37	0.46	15.93	0.21	15.73	17.98	15.06	12.98	0.22	0.38	10.64	1.08	0.24	6.38	9.21	8.07	0.19
Summer	14.29	15.40	.02	15.03	.15	16.49	17.11	.08	16.66	.08	17.54	18.79	15.01	12.34	.03	.08	9.48	1.21	.37	8.02	1.50	1.16	.02
Winter	12.26	10.05	.41	8.98	1.24	15.78	15.22	.92	15.42	.41	15.60	18.95	17.79	17.07	.33	.04	------	------	------	------	17.17	18.97	.31
Summer transitional	13.88	14.62	.12	14.66	.49	19.47	14.51	.10	15.81	.04	18.69	14.69	10.82	7.99	.04	.10	------	------	------	------	2.60	2.44	.02
Winter transitional	13.36	10.61	.30	10.94	1.74	18.41	13.50	.67	14.98	.34	14.72	18.44	18.41	12.72	.56	.60	------	------	------	------	13.79	8.33	.05
Main stream corrected:																							
Year	------	12.76	------	12.16	------	16.02	14.32	------	14.42	------	14.02	16.25	13.30	------	------	------	------	------	------	------	------	------	------
Summer	------	15.40	------	15.00	------	16.37	16.94	------	16.58	------	17.27	18.02	14.66	------	------	------	------	------	------	------	------	------	------
Winter	------	10.05	------	8.57	------	14.13	13.60	------	12.85	------	12.53	15.97	14.88	------	------	------	------	------	------	------	------	------	------
Summer transitional	------	14.62	------	14.87	------	15.98	13.92	------	15.12	------	12.94	14.06	9.58	------	------	------	------	------	------	------	------	------	------
Winter transitional	------	10.61	------	10.04	------	16.38	11.40	------	12.26	------	11.67	15.40	12.30	------	------	------	------	------	------	------	------	------	------
ORGANIC NITROGEN																							
Observed values:																							
Year	12.94	16.29	.82	16.88	6.88	26.24	24.36	2.56	26.35	1.68	25.84	23.06	18.44	20.00	1.15	1.53	16.66	1.57	.96	15.98	32.13	29.43	1.47
Summer	8.30	16.72	.06	16.07	1.06	11.91	13.33	.64	13.36	.13	13.69	13.26	14.21	15.17	.43	1.13	13.22	1.84	1.26	15.13	18.48	15.72	.12
Winter	14.84	18.50	1.35	19.11	8.38	38.69	37.80	3.54	31.94	1.72	30.96	27.37	20.72	22.14	1.57	1.82	------	------	------	------	41.32	48.14	2.10
Summer transitional	10.55	14.46	.42	11.36	3.44	17.02	20.66	1.05	20.74	.28	21.09	18.60	16.64	17.54	.56	2.46	------	------	------	------	17.88	26.60	.14
Winter transitional	20.78	12.37	1.64	16.16	15.64	44.29	42.40	5.04	46.78	5.64	43.96	36.28	21.60	25.30	1.71	.30	------	------	------	------	56.66	33.56	.10
Main stream corrected:																							
Year	------	16.29	------	16.06	------	15.54	16.60	------	16.06	------	14.01	11.32	6.00	------	------	------	------	------	------	------	------	------	------
Summer	------	16.72	------	16.01	------	10.79	12.30	------	11.30	------	12.47	11.28	12.65	------	------	------	------	------	------	------	------	------	------
Winter	------	18.50	------	17.76	------	22.96	18.60	------	18.66	------	18.20	12.37	5.73	------	------	------	------	------	------	------	------	------	------
Summer transitional	------	14.46	------	10.94	------	12.77	16.76	------	15.24	------	15.21	12.88	10.86	------	------	------	------	------	------	------	------	------	------
Winter transitional	------	12.37	------	16.81	------	28.66	23.10	------	21.44	------	13.30	7.62	−9.00	------	------	------	------	------	------	------	------	------	------
KJELDAHL NITROGEN																							
Observed values:																							
Year	26.09	29.05	1.03	29.26	7.73	43.31	39.73	3.02	42.28	1.79	41.58	41.01	33.49	32.98	1.37	1.89	27.30	2.95	1.22	22.36	41.34	37.50	1.66
Summer	21.63	31.02	.09	31.10	1.20	28.31	29.39	.70	30.02	.16	31.24	31.54	29.39	27.51	.45	1.21	22.70	3.05	1.75	23.15	20.07	16.88	.15
Winter	27.10	28.55	1.76	28.09	9.62	54.47	42.13	4.46	47.36	2.13	46.50	46.22	38.52	40.21	2.20	2.46	------	------	------	------	58.50	66.11	2.43
Summer transitional	24.43	29.07	.54	26.04	3.92	37.10	35.13	1.75	36.86	.32	34.76	32.40	26.96	25.58	.60	2.56	------	------	------	------	21.42	29.44	.16
Winter transitional	34.64	28.98	1.94	30.10	30.38	62.62	56.90	5.72	61.74	5.68	56.60	54.72	37.00	38.02	2.27	.90	------	------	------	------	69.47	42.06	.73
Main stream corrected:																							
Year	------	29.05	------	28.22	------	34.86	30.96	------	30.80	------	28.08	27.46	19.98	------	------	------	------	------	------	------	------	------	------
Summer	------	31.02	------	31.01	------	27.11	29.20	------	27.89	------	29.80	29.30	27.31	------	------	------	------	------	------	------	------	------	------
Winter	------	28.55	------	28.32	------	43.09	31.74	------	31.51	------	27.92	28.34	20.56	------	------	------	------	------	------	------	------	------	------
Summer transitional	------	29.00	------	26.51	------	22.04	30.69	------	30.36	------	28.26	28.80	20.44	------	------	------	------	------	------	------	------	------	------
Winter transitional	------	28.98	------	27.18	------	60.30	34.57	------	28.70	------	24.67	28.00	2.34	------	------	------	------	------	------	------	------	------	------

TABLE No. 30.—*Yearly and seasonal average sanitary chemical analyses of Illinois River and tributaries*—Continued

[Results in quantity units; parts per million × thousands of second-feet discharge]

	Summit	292	Des Plaines	286	Kankakee	263	240	Fox	227	Vermilion	196	179	166	148	Mackinaw	Spoon	101	Sangamon	Crooked Creek	77	43	26	Macoupin
NITROGEN OXIDES																							
Observed values:																							
Year	1.25	1.58	1.80	4.35	12.63	13.61	17.82	4.11	22.18	3.50	26.69	27.05	28.27	29.62	2.07	1.78	8.94	1.54	0.35	11.94	48.69	49.28	0.71
Summer	.23	.00	.00	.29	.54	.53	.61	.07	.46	.11	.88	1.21	1.64	2.65	.27	.42	5.98	.66	.22	7.13	12.80	14.11	.04
Winter	2.11	2.79	3.52	8.32	20.83	24.18	27.19	8.28	36.87	5.94	44.69	42.88	44.61	45.18	3.25	2.47					86.92	81.07	1.45
Summer transitional	.00	.42	.20	.13	4.10	1.52	5.07	1.40	5.24	1.18	12.42	12.88	18.92	22.94	1.06	1.14					42.70	44.78	.88
Winter transitional	2.64	3.46	3.45	8.57	28.70	30.90	46.14	6.52	32.76	7.58	55.72	88.69	56.92	57.10	4.11	3.40					98.82	98.88	1.60
Main stream corrected:																							
Year		1.58		2.56		−.82	2.39		3.64		4.65	5.01	6.24										
Summer		.00		.29		−.02	.06		−.06		.29	.44	1.20										
Winter		2.79		4.80		−.21	2.75		4.24		6.12	5.32	6.94										
Summer transitional		.42		−.14		−2.85	.70		−.52		5.46	5.94	11.92										
Winter transitional		3.46		5.12		−1.24	12.99		14.10		9.47	12.34	10.88										
TOTAL NITROGEN																							
Observed values:																							
Year	27.34	30.63	2.82	33.61	20.35	56.92	57.55	7.13	64.46	5.29	66.28	68.08	61.78	62.60	3.49	3.65	37.24	4.50	1.57	34.30	90.68	88.79	2.37
Summer	21.86	31.63	.09	31.39	1.74	28.92	31.10	.77	30.47	.27	32.14	32.78	30.87	30.17	.74	1.62	28.69	3.71	2.08	30.28	32.65	30.99	.19
Winter	29.30	31.24	5.28	38.42	30.48	78.60	70.28	12.74	84.28	8.07	90.58	90.11	88.13	83.39	5.43	4.94					121.82	121.17	3.58
Summer transitional	24.43	28.82	.80	26.18	8.02	26.61	40.20	3.15	41.80	1.50	47.28	48.28	45.88	46.48	1.06	3.08					65.12	74.22	.23
Winter transitional	37.28	27.46	5.34	37.08	49.08	92.88	102.08	12.24	114.50	13.27	114.22	115.22	98.88	95.11	6.33	4.36					168.30	170.95	6.73
Main stream corrected:																							
Year		30.63		30.77		33.74	34.37		34.14		32.68	32.46	29.17										
Summer		31.63		31.30		27.09	20.26		28.74		30.08	29.74	28.51										
Winter		31.24		31.12		42.98	34.49		35.75		34.04	32.58	28.88										
Summer transitional		29.82		25.36		20.30	31.35		20.84		23.74	32.82	32.48										
Winter transitional		27.46		32.28		22.06	48.58		47.80		24.34	35.31	12.94										
OXYGEN CONSUMED																							
Observed values:																							
Year	57.60	66.51	5.21	74.22	53.03	139.99	145.57	17.67	159.14	10.41	161.01	133.98	118.07	134.70	7.96	10.90	84.49	18.00	9.96	108.63	222.88	248.78	14.62
Summer	49.50	64.30	.44	63.35	7.41	76.67	78.07	3.72	76.96	.44	69.96	61.06	65.14	76.06	2.01	6.25	67.30	14.41	13.76	110.19	134.12	168.04	1.60
Winter	59.59	64.94	7.09	76.45	55.43	147.58	137.80	23.38	171.15	12.00	166.75	142.88	115.40	137.21	10.46	13.20					282.89	287.31	18.07
Summer transitional	50.60	74.50	2.42	70.08	27.90	110.75	115.53	13.28	119.16	2.76	123.36	118.97	112.82	120.15	4.26	12.03					[illegible]	[illegible]	1.44
Winter transitional	72.79	66.50	12.42	94.36	102.77	278.53	311.87	36.80	328.74	33.80	297.65	308.34	220.89	255.62	16.72	11.77					346.47	[illegible]	46.87
Main stream corrected:																							
Year		66.51		69.02		81.75	87.32		82.23		66.20	47.60	31.70										
Summer		64.30		62.92		69.90	70.22		67.34		59.74	46.36	52.16										
Winter		64.94		68.70		86.97	74.69		84.00		68.20	45.08	16.91										
Summer transitional		74.50		67.68		80.47	86.52		78.58		72.06	72.64	68.46										
Winter transitional		66.50		81.98		103.33	136.67		116.73		51.90	22.38	−24.98										

The amounts of suspended solids were determined in the daily samples obtained from certain selected sampling points in the river stretch from Lockport to Peoria. The monthly average values of these determinations, computed from the daily analytical results, are presented in Table No. 31, together with the seasonal and yearly averages.

TABLE No. 31.—*Monthly average amounts of suspended solids in samples from certain parts of Illinois River*

Month	Suspended solids in parts per million at station—				
	292	286	263	179	166
1921					
August		[1] 46.5	[1] 44.7	[2] 22.6	[2] 37.2
September	18.2	34.6	58.3	25.3	53.6
October	23.8	38.8	48.8	22.7	24.5
November	39.1	52.8	66.6	46.2	22.7
December	61.8	65.2	61.3	37.1	21.9
1922					
January	30.6	36.9	43.5	19.3	21.9
February	24.3	32.8	46.8	22.8	19.3
March	27.4	54.7	98.5	59.3	37.8
April	29.1	65.9	164.3	60.8	35.9
May	26.8	46.1	60.3	44.6	22.1
June	35.0	56.8	83.8	30.1	28.9
July	29.3	46.9	47.1	14.4	37.7
August	24.7	36.3	37.7	17.6	22.8
Averages					
All months	30.8	47.3	67.0	32.5	30.5
September, 1921, to August, 1922	30.8	47.3	68.8	33.3	30.0
Summer	26.8	44.4	54.3	22.0	37.9
Winter	36.0	47.4	62.5	34.6	25.2
Summer transitional	25.3	42.4	59.0	33.6	23.3
Winter transitional	34.1	59.4	115.4	53.5	29.8

[1] Determinations begun Aug. 29, 1921.
[2] Determinations begun Aug. 16, 1921.

II. DISCUSSION

A comprehensive discussion of the sanitary chemical results presented above and the evidence they supply of the degree of purification taking place throughout the course of the stream will not be attempted here. However, it may be of interest to note briefly some of the outstanding features concerning the burden of pollution and the seasonal changes in the sewage load which these data portray.

INTENSITY OF POLLUTION IN THE MAIN DRAINAGE CANAL

The most logical measure of the pollution occurring in the main drainage canal is perhaps one in terms of sewage. Since the sewage of different cities varies in the concentration of polluting substances, it is first necessary to define the properties of the sewage to be used as a standard of measurement. Such a standard sewage may be described as a combined sewage which contains street washings and storm water, and which, it is believed, constitutes a more measurable basis of comparison than the strictly domestic sewage from household wastes alone. The analytical data used to develop this standard are presented in Table No. 32.

TABLE No. 32.—*Base data pertaining to combined sewage*

Place	Period covered by analyses	Contributing population (thousands)	Gallons per capita daily	Parts per million (observed values)			Parts per million (basis of 100 gallons daily)			Grams per capita daily		
				Free ammonia	Total nitrogen	Oxygen consumed (30-minute boil)	Free ammonia $\frac{(1)\times(2)}{100}$	Total nitrogen $\frac{(1)\times(3)}{100}$	Oxygen consumed (30-minute boil) $\frac{(1)\times(4)}{100}$	Free ammonia $\frac{(5)}{2.64}$	Total nitrogen $\frac{(6)}{2.64}$	Oxygen consumed (30-minute boil) $\frac{(7)}{2.64}$
			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Columbus, Ohio [1]	1904-5	75	121	11.0	20.0	[5] 93	13.3	24.2	113	5.0	9.2	42.7
Boston, Mass.[2]	1905-7	670	200	13.9	23.0	56	27.8	46.0	112	10.5	17.4	42.4
Chicago, Ill.[3]	1909-10	2,185	290	8.8	16.4	38	25.4	47.4	110	9.6	17.9	41.6
Providence, R. I.[2]	1909	234.3	102	18.4	21.2	[6] 255	18.8	21.6		7.1	8.2	98.5
Lawrence, Mass.[1]	1898-1910			[4] 22.9		[6] 120						
Washington, D. C.[3]	1913-14	300	204	7.1	14.0	42	14.5	28.6	86	5.5	10.8	32.4
Average [7]										7.5	11.4	51.5
Average [8]							20.0	33.5	105	7.5	12.7	39.8

[1] Stabler and Pratt; Water Supply Paper No. 235, U. S. Geological Survey, 1909.
[2] Metcalf and Eddy, American Sewage Practice, Vol. III, Disposal of Sewage (1915), pp. 176-181.
[3] Unpublished data, U. S. Public Health Service.
[4] Omitted. Method of analysis used not comparable with other values.
[5] Computed from results of 5-minute boiling test using a factor of 1.82.
[6] Computed from results of 2-minute boiling test using a factor of 2.36.
[7] Omitting the total nitrogen value for Chicago.
[8] Including the total nitrogen value for Chicago and omitting the abnormally high oxygen consumed value for Providence. This high value due to the presence of unusual amounts of chlorides. See also 6.

Although all analytical data included in this table are averages of results obtained over long periods of time, the agreement between the observed parts per million content is far from uniform. This is due in great measure to a very uneven per capita water consumption. When allowance is made for this factor on the basis of a uniform rate of water usage (100 gallons per capita daily in this instance) and values derived on this basis for the daily contribution of consituents in grams per capita, the discrepancies in the observed or uncorrected results are harmonized to some extent. Reasons for the high oxygen consumed value of Providence sewage are perhaps to be found in the abnormally high chloride content of the sewage, and may also be connected with the fact that considerable uncertainty exists in the choice of a factor for the conversion of the 2-minute boiling results into terms of the standard procedure of immersing the samples in boiling water for 30 minutes.

The values of this average sewage may now be compared with the analyses of the main drainage canal at station 292. It will be assumed that the composition of this water does not change appreciably during the time required for its passage from Chicago to the sampling point in question. With this reservation, and within the limitations of our definition of a standard sewage, the measures of the extent of pollution of the canal water may be derived as in Table No. 33.

TABLE No. 33.—*Relative pollution of main drainage canal at station 292, as compared with standard sewage*

[Results in parts per million]

Constituent	Standard sewage (a)	Yearly average, station 292 (b)	Percentage strength of canal water =b/a×100 (c)
Free ammonia	20.0	1.47	7.35
Total nitrogen	33.5	3.54	10.57
Oxygen consumed	105.0	7.59	7.22
Average			8.38

Somewhat different values of this relative intensity of pollution are obtained if Chicago sewage is substituted for the standard sewage as defined above. In this case the results as given in Table No. 34 are obtained, when the Chicago sewage is referred to a 100-gallon per capita basis.

TABLE No. 34.—*Relative pollution of main drainage canal at station 298, as compared with Chicago sewage*

[Results in parts per million]

Constituent	Chicago sewage (a)	Yearly average, station 298 (b)	Percentage strength of canal water (c)
Free ammonia	25.4	1.47	5.79
Total nitrogen	47.4	3.64	7.68
Oxygen consumed	110.0	7.60	6.90
Average			6.79

The relative strength of the effluent in the canal may be roughly checked in another way. The yearly average discharge of the canal at Lockport is, from Table No. 25, 8,660 cubic feet per second, which, for the estimated equivalent population of 4,720,000 tributary to the canal, corresponds to 1,185 gallons per capita daily. Based on the standard sewage contribution of 100 gallons per capita, the amount of such normal sewage in the canal by this method of computation is 8.43 per cent of the total flow.

In deriving the above values for the proportion of sewage in the drainage canal, no account has been taken of the polluting constituents of the diluent. Analyses of Lake Michigan water as obtained from samples collected and analyzed at the Thirty-ninth Street pumping station of the Sanitary District of Chicago are presented in Table No. 35. However, much of the pollution which this lake water contains is doubtless originally contributed by the Chicago population, the composition of normal Lake Michigan water probably differing considerably from these values, which fact would tend to lessen the necessity for applying such a correction.

TABLE No. 35.—*Analytical content of Lake Michigan water at Thirty-ninth Street, Chicago*[1]

[Results in parts per million]

Months	Free ammonia	Kjeldahl nitrogen	Nitrogen oxides	Total nitrogen	Oxygen consumed, 30-minute boil
1921					
October	0.16	0.60	0.30	0.90	3.35
November	.28	.73	.27	1.00	3.59
December	.10	.90	.40	1.30	3.39
1922					
January	.06	.80	.50	1.30	3.40
February	.07	.67	.23	.90	2.73
March	.20	.80	.07	.87	3.80
April	.13	.87	.13	1.00	3.93
May	.13	.60	.07	.67	3.60
June	.53	.87	.00	.87	2.73
July	.17	.67	.00	.67	3.47
August	.15	.90	.00	.90	3.80
September	.17	.93	.03	.97	2.80
Average	.18	.78	.15	.94	3.76

[1] Analyses by Sanitary District of Chicago.

PER CAPITA CONTRIBUTION OF POLLUTING CONSTITUENTS

The per capital amounts of various chemical constituents contributed by the population of Chicago to the main drainage canal at Summit may be readily computed from the quantity units of the several ingredients as given in Table No. 27, knowing the population contributing wastes. This may be done most readily by the application, to the quantity unit data, of a conversion factor developed as follows:

$$\text{Grams per day} = \text{Quantity units} \times 2{,}446{,}589$$

Then for a population of 2,834,400 (see Table No. 12)

$$\text{Grams per capita} = \text{Quantity units} \times \frac{2{,}446{,}589}{2{,}834{,}400}$$

$$= \text{Quantity units} \times 0.86318$$

And similarly, for the total equivalent population, including industrial wastes of 4,298,100 (see Table No. 12),

$$\text{Grams per capita} = \text{Quantity units} \times 0.56923$$

By applying these factors to the average quantity units of the various constituents observed at Summit sampling station as given in Table No. 27, the per capita daily contributions of constituents in the main drainage canal at that point, as given in Table No. 36, are obtained, based on the actual and on the total equivalent populations, respectively.

TABLE No. 36.—*Grams per capita contribution of polluting constituents to water of main drainage canal at Summit*

Constituents	Yearly average	Summer months	Winter months	Standard sewage
(*a*) Based on actual sewered population of 2,834,400:				
Free ammonia	11.36	11.50	10.58	7.5
Organic nitrogen	11.17	7.16	12.81	
Kjeldahl nitrogen	22.52	18.66	23.39	
Nitrogen oxides	1.08	.29	1.91	
Total nitrogen	23.60	18.87	25.30	12.7
Oxygen consumed	49.73	42.73	51.44	29.8
(*b*) Based on total equivalent population of 4,298,100:				
Free ammonia	7.49	7.58	6.98	7.5
Organic nitrogen	7.37	4.72	8.45	
Kjeldahl nitrogen	14.85	12.31	15.43	
Nitrogen oxides	.71	.19	1.26	
Total nitrogen	15.56	12.44	16.68	12.7
Oxygen consumed	32.80	28.18	33.92	29.8

It is apparent that the actual per capita contribution of polluting constituents as given in the first part of the table is considerably above the normal amounts observed in sewage unaffected by industrial wastes. This is due to the rather extensive quantities of organic industrial wastes present in the Chicago sewage. However, when the per capita contribution is computed on the basis of the total equivalent population inclusive of industrial wastes, as in the second part of Table No. 36, the amounts of polluting constituents correspond much more closely with those observed in the normal sewage.

It is also of interest to observe the per capita change in the organic constituents of the Chicago sewage load as it passes downstream from station 292 to station 166. Such a comparison is readily made by comparing the data of these stations as given in Table No. 28 and applying the conversion factor of 0.86318 to the respective differences in quantity units of the various constituents at the two stations. These changes are given in Table No. 37. Thus during the travel from station 292 to station 166 the yearly average change in free ammonia and in nitrogen oxides amounts to an increase of 0.49 and 4.02 grams per capita per day, respectively, while organic nitrogen, Kjeldahl nitrogen, total nitrogen, and oxygen consumed values decrease in the amounts shown during the same period of time.

TABLE No. 37.—*Change in per capita amounts of organic constituents contributed by Chicago during time of passage from station 292 to station 166*

[Figures in grams per capita; plus (+) indicates an increase and minus (−) a decrease from station 292 to station 166]

Constituent	Yearly average	Summer months	Winter months
Free ammonia	+0.49	−0.64	+4.12
Organic nitrogen	−8.36	−3.09	−11.03
Kjeldahl nitrogen	−7.87	−3.73	−6.91
Nitrogen oxides	+4.02	+1.04	+2.81
Total nitrogen	−3.85	−2.69	−4.10
Oxygen consumed	−30.64	−7.89	−41.51

SEASONAL VARIATIONS IN THE CHEMICAL CONSTITUENTS OF THE ILLINOIS RIVER

The discharge at station 292 varies only between definite, narrow limits throughout the year, as may be observed from the data in Table No. 19 of the volume of flow at the various sampling stations. The flow at station 286 is likewise relatively constant, being influenced only by fluctuations in the flow of the Des Plaines River. However, the stream flow at other downstream points is markedly affected by the contributions of tributaries, resulting in definite maxima during the months of April and October. This condition has an important influence on the concentration of organic materials throughout the lower reaches of the river.

The temperatures of the river water throughout its course are presented in Table No. 38. Temperatures at downstream points are usually a few degrees higher than at the upper observation stations, maximum differences occurring in May and June. However, the variations in water temperature throughout the stream length are slight and are probably of no sanitary significance.

TABLE No. 38.—*Monthly average temperatures of the Illinois River at various sampling stations*

[Observations in degrees centigrade]

Month	Sampling station													
	Summit	292	286	263	240	227	196	179	166	148	101	77	43	20
1921														
July	24.7				26.1	26.8	27.7	27.6	28.2	28.4	28.9	28.9	28.5	29.3
August	21.8	22.7	23.0	23.1	24.0	23.4	24.2	23.8	24.0	24.4	26.2	26.1	26.4	25.7
September	19.2	20.1	20.1	21.0	21.7	20.9	21.6	21.4	22.0	22.9	24.3	23.6	22.7	23.6
October	12.4	13.8	13.7	13.5	14.0	13.4	13.0	13.2	13.2	14.0	14.7	14.8	14.1	14.5
November	8.0	7.4	6.9	7.6	6.1	6.4	7.2	7.5	8.0	7.4	11.4	11.9	7.8	7.4
December	4.2	2.2	2.1	2.7	2.6	2.5	2.9	2.9	2.0	2.8			4.2	4.3
1922														
January	1.2	.2	.8	1.1	.5	.4	.9	.1	.3	1.0				
February	2.0	1.0	1.5	1.8	.0	.9	1.2	.5	.9	.5			1.7	1.9
March	4.0	2.7	4.6	4.7	3.2	4.8	4.5	4.4	5.5	4.9			5.8	6.2
April	8.3	8.6	9.4	10.3	9.2	10.1	10.4	10.3	11.2	9.6			9.0	9.0
May	14.5	15.0	15.0	16.3	[1]17.0	17.2	18.6	18.4	19.2	18.5			20.2	20.1
June	19.7	20.9	20.5	20.6	21.3	21.3	20.5	20.5	24.2	24.8			26.6	25.9
July	22.1	22.4	22.6	22.7	24.0	22.9	24.2	24.6	24.8	25.8			28.2	28.2
August	23.1	23.8	22.7	23.5	22.4	23.7	25.1	24.3	24.7	25.4			26.4	26.0

[1] Average of temperature at 247.2 and 236.8.

The quantity units of free ammonia, both observed and as corrected for tributary contribution, have been plotted in Figure 11. At most stations the variations range from 10 to 20, but the fluctuations are far from uniform. Thus the increase in free ammonia at the upper stations during the months of March, April, and May is paralleled by a decrease at the lower stations. As a rule, however, there is a slight increase in the free ammonia content during the months of May, June, and July, at least at points below station 263. On the whole, the fluctuations in the free ammonia are relatively small and are very little affected by the enormous variations in the total volume of water. This follows, of course, from the fact that the proportion of free ammonia in the tributaries is very low at all times of the year, and it may be taken as an indication that the amount of free ammonia leached out from the soil is very small.

The seasonal variation in the nitrate content of the river is well illustrated by the symmetrical curves presented in Figure 12. As in the case of the Kjeldahl nitrogen and organic nitrogen values, a maximum is reached in the month of April. The relatively high values reached in the month of December are evidently due to the presence of an abundance of nitrates in the soil, a condition which does not obtain during the heavier spring rains. The indication is that the production of nitrates is at a standstill from July to October, at all points above station 166. The apparent increase during the months of December and January is to be corrected for the nitrates in the run-off from the main stream itself, as well as for the months of March, April, and May. At times there is evidence that nitrates are actually being reduced, although in such cases this may be due to unavoidable experimental errors.

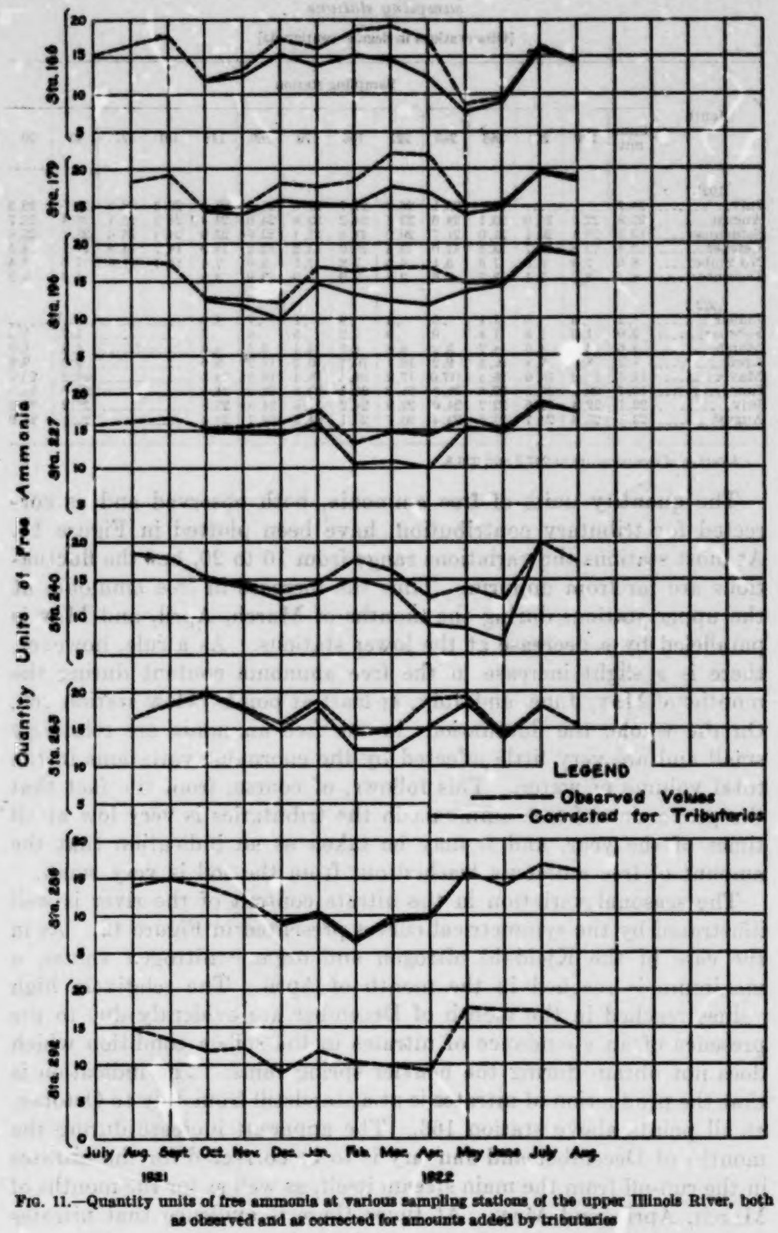


FIG. 11.—Quantity units of free ammonia at various sampling stations of the upper Illinois River, both as observed and as corrected for amounts added by tributaries

106a

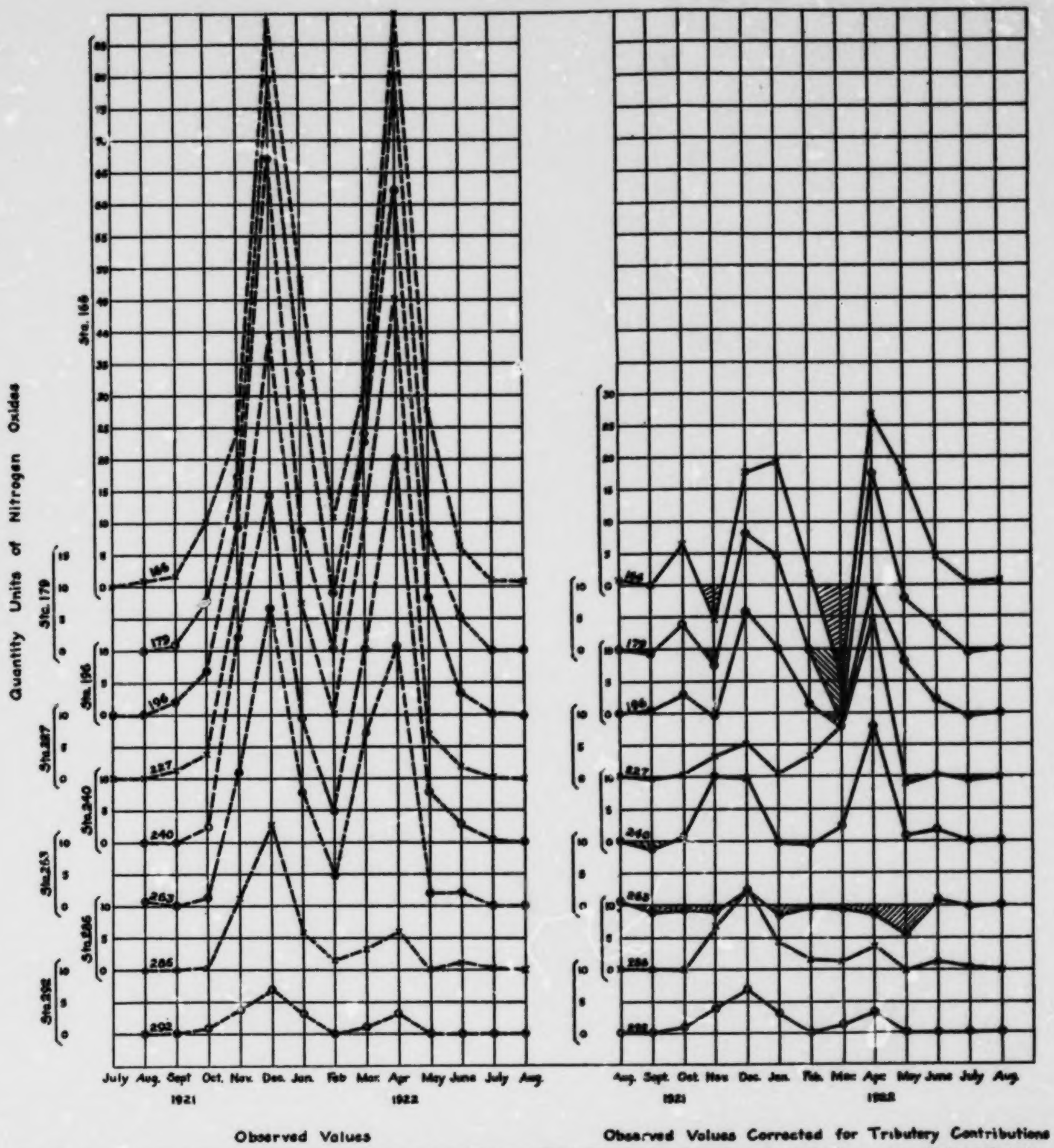
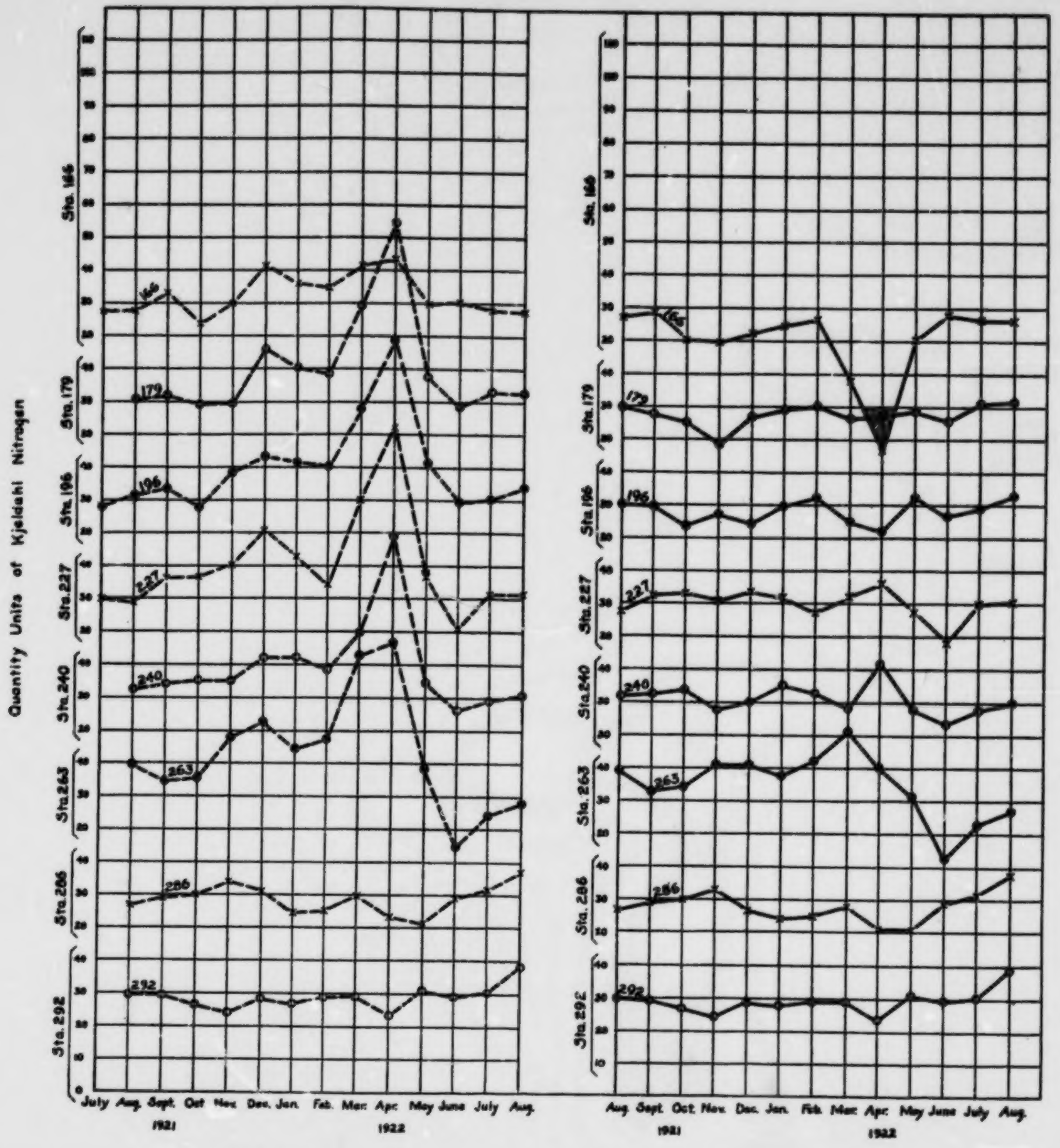


FIG. 12.—Quantity units of nitrogen oxides at various sampling stations of the upper Illinois River, both as observed and as corrected for amounts added by tributaries

44602—27. (Face p. 106.)



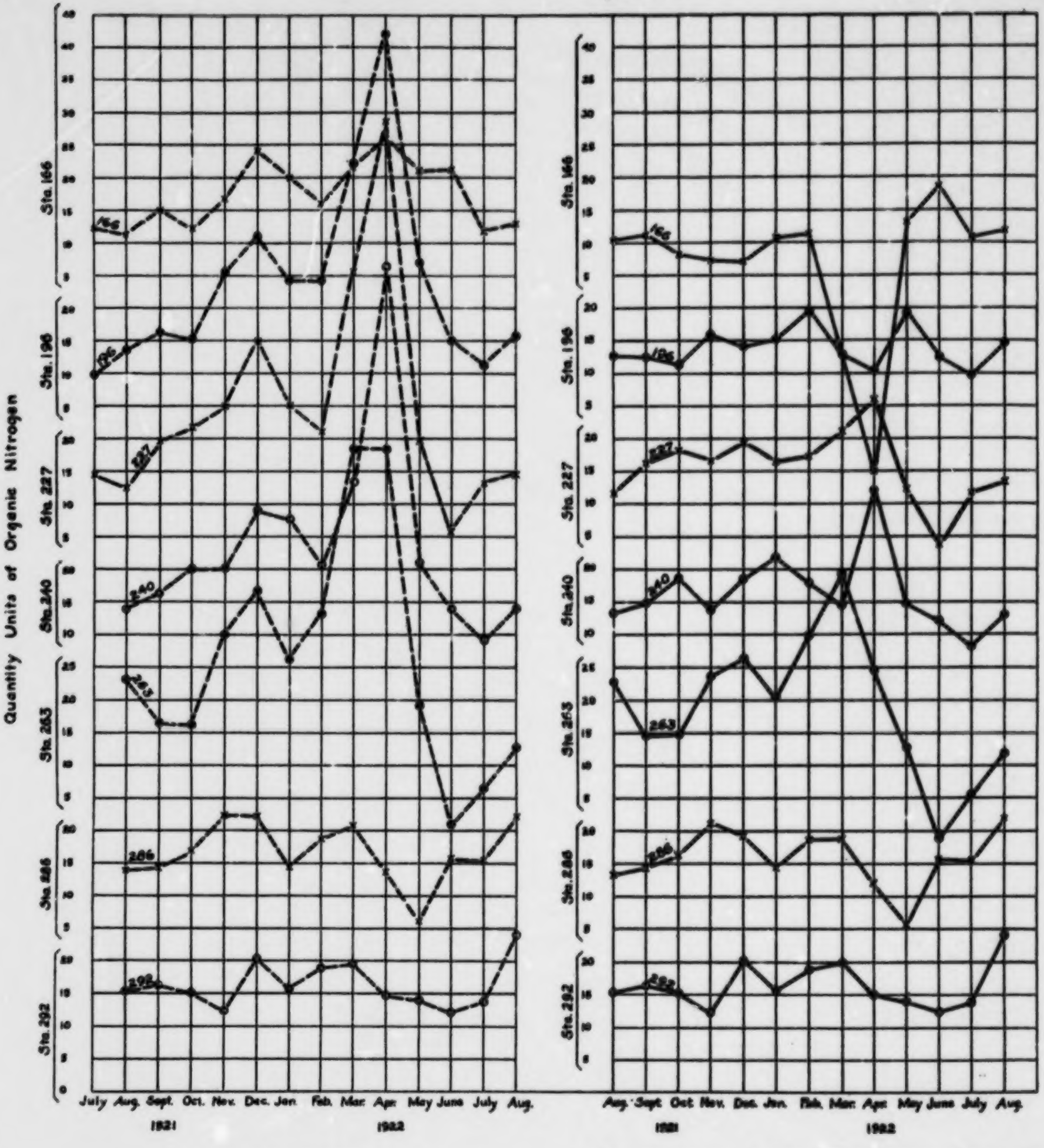
Observed Values

Observed Values Corrected for Tributary Contributions

Fig. 13.—Quantity units of Kjeldahl nitrogen at various sampling stations of the upper Illinois River, both as observed and as corrected for amounts added by tributaries

44602—27. (Face p. 107.) No. 1

106c



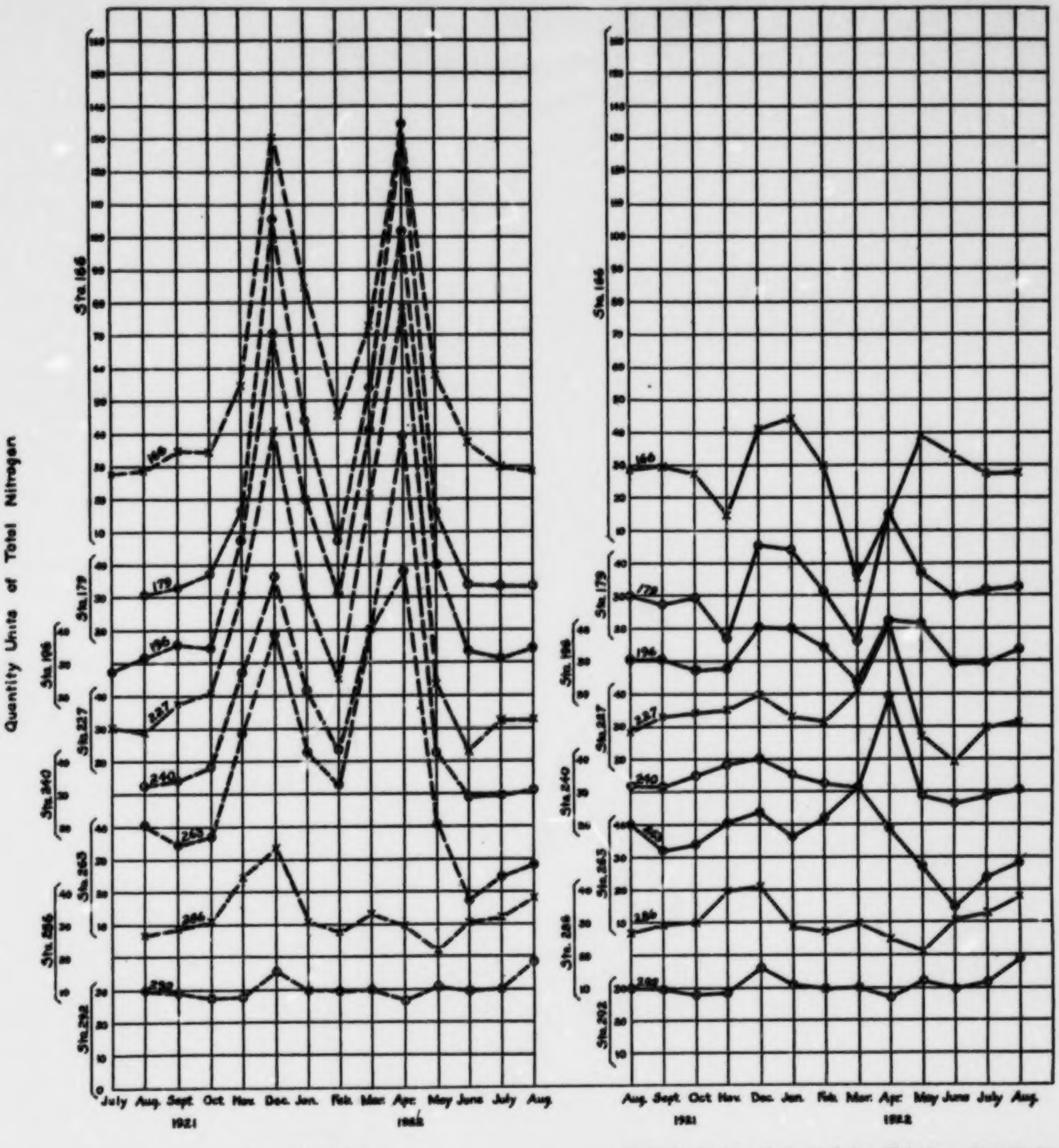
Observed Values

Observed Values Corrected for Tributary Contributions

FIG. 14.—Quantity units of organic nitrogen at various sampling stations of the upper Illinois River, both as observed and as corrected for amounts added by tributaries

44602—27. (Face p. 107.) No. 2

106 d



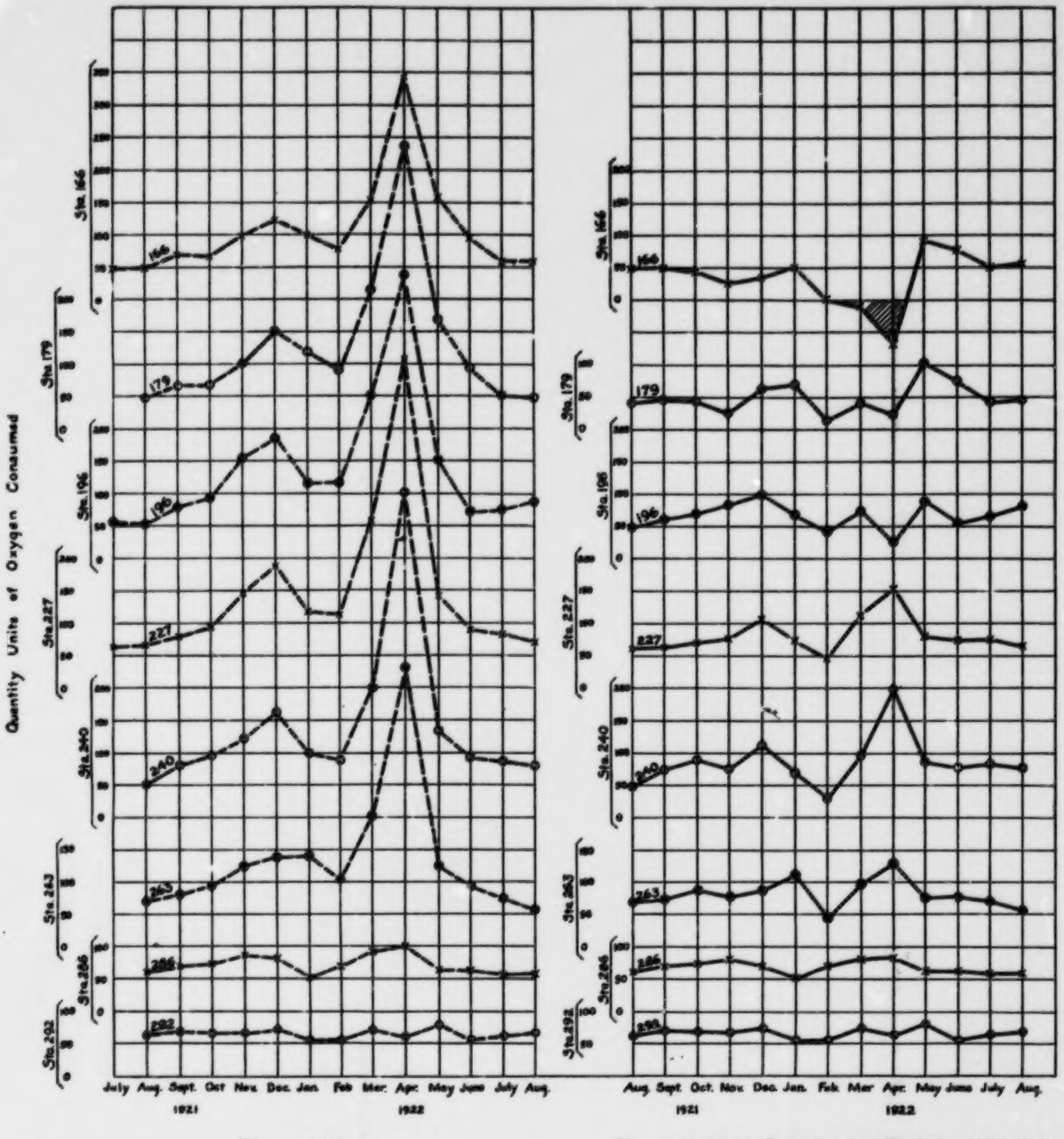
Observed Values

Observed Values Corrected for Tributary Contributions

FIG. 15.—Quantity units of total nitrogen at various sampling stations of the upper Illinois River, both as observed and as corrected for amounts added by tributaries

44602—27. (Face p. 107.) No. 3

106e



Observed Values

Observed Values Corrected for Tributary Contributions

FIG. 16.—Quantity units of oxygen consumed at various sampling stations of the upper Illinois River, both as observed and as corrected for amounts added by tributaries

44602—27. (Face p. 107.) No. 4

The Kjeldahl nitrogen seasonal variations, both as observed and as corrected for tributary contributions, are illustrated in Figure 13. As would be expected, these curves closely resemble those given in Figure 14 referring to the organic nitrogen. In both cases the maximal and minimal values are evidently closely related to the volume of flow. The violent fluctuations in observed values of both constituents are considerably reduced when corrections are applied for the nitrogen contribution of the various tributaries.

The total nitrogen values, both observed and as corrected for tributaries, illustrated in Figure 15 present the same general features as do the data of the various components. On the whole, it appears that the total nitrogen is relatively constant throughout the year. The indication is that the loss of nitrogen by gasification, if occurring at all, is negligibly small.

The oxygen-consumed results, plotted in Figure 16, show a marked correspondence with changes in the volume of discharge. In part, the observed increase may be credited to the fact that, using the permanganate oxygen consumed method, disproportionately high results are obtained when a sample is progressively diluted. The results indicate that, for all practical purposes, the oxygen-consumed value of the Illinois is relatively constant at any given station throughout the year, the only notable exceptions being connected with the flood conditions during the month of April.

The observed values in suspended solids have not been corrected for amounts added by tributaries, since no determinations of this constituent in the tributaries were made. The observed values at station 292 are reasonably constant throughout the year, the greatest fluctuations occurring at station 263, which is below the mouth of the Kankakee. These variations are doubtless due in part to the matter in suspension brought in by the larger tributaries and in part to the scouring out of bottom sediments in the main channel during times of increased velocity of flow. The generally higher values of suspended matter at station 166 during the summer months are believed a result of the heavy plankton growths occurring in Lake Peoria during the warm season. The considerable increase in suspended solids between stations 292 and 286 may be occasioned by the coagulation of soluble organic matter formed during the processes of biochemical changes.

COMPARISON WITH RESULTS OF PREVIOUS INVESTIGATIONS

Extensive surveys[3] undertaken from 1896 to 1901 have furnished data which can be used for the purpose of estimating progressive changes in the pollution of the river. It is to be noted that in the earlier studies the distillation method was used for the estimation of free ammonia, whereas in the recent studies the direct Nesslerization method was adopted. With this exception, the analytical methods used were very much the same.

---

[3] Chemical Survey of the Waters of Illinois. Report for the years 1897–1902, by Arthur William Palmer, Sc. D., University of Illinois, 1903.

By inspection of Table No. 39 it appears that the free ammonia content of the upper river has decreased considerably since 1899.

TABLE No. 39.—*Free ammonia results—Yearly averages in parts per million*

Station	Year						
	1896	1897	1898	1899	1900	1901	1921-22
285				14.92	2.97	2.40	1.88
263	2.55	3.78	4.11	[1] 8.9	2.98		1.28
240				4.99	1.21	[2] .97	1.17
223	.97	1.73	1.40	[3] 2.54	.98		[4] 1.09
166		[5] .84	.86	1.02	.64	.65	.91

[1] May to December.
[2] July to October.
[3] February to December.
[4] Results of 1921-22. Samples from station 226.
[5] April to December.

The high value of 14.92 parts per million for 1899 is of course connected with the practical absence of dilution, the sudden decrease to 2.97 parts per million in 1900 marking the opening of the main drainage canal. Passing from station 285 to the downstream stations, it is apparent that the progressive changes in the free ammonia were by no means as marked during the 1921-22 period as was formerly the case. In fact, at stations 226 and 166 the free ammonia content is now slightly greater than in 1900. The difference, however, is slight and, bearing in mind the known difference in analytical procedure, is probably negligible.

The organic nitrogen values presented in Table No. 40 all show a marked tendency to decrease progressively in passing from the upper to the lower stations. Owing to the variations in analytical procedure in the estimation of free ammonia, it is perhaps not justifiable to institute comparisons between the earlier results and those of the recent studies. A similar tendency, however, is manifested by the Kjeldahl nitrogen results presented in Table No. 41. The indication is that this quantity diminished much more during 1901 than in 1921-22, although this greater decrease may be accounted for by an increase in the pollution of the tributaries since 1901.

TABLE No. 40.—*Organic nitrogen results—Yearly averages in parts per million*

Station	Year						
	1896	1897	1898	1899	1900	1901	1921-22
265				4.50	1.67	0.96	1.88
263	1.44	1.61	2.40	1.83	1.16		1.66
240				1.11	.85	.90	1.65
226	1.20	1.25	1.16	1.26	.94		1.47
166		1.01	.83	1.11	.77	.73	1.69

TABLE No. 41.—*Kjeldahl nitrogen results—Yearly averages in parts per million*

[Sum of free ammonia and organic nitrogen results]

Station	Year						
	1896	1897	1898	1899	1900	1901	1921-22
265				19.42	4.54	2.45	2.26
263	4.99	7.30	6.60	10.82	2.24		2.03
240				6.10	2.16	1.67	2.72
226	2.22	2.96	2.36	2.57	1.90		2.50
166		1.83	1.69	2.13	1.41	1.67	1.94

Referring to the nitrate values summarized in Table No. 42, it appears that the parts per million content of nitrates was higher in 1900 and 1901 than in 1921–22. It is also to be noted that, in the period from 1896 to 1901, a maximum of nitrification appears to have been reached at station 240, after which the nitrogen oxides diminished progressively until station 166. Commenting on this curious result, Palmer[3] (p. 96) says: "This is due not to dilution, for no considerable dilution occurs between these points, but to the utilization of nitrates by the vegetation which is extremely abundant in the broad lake-like stretches of the river between these two points." This effect, however, was not noted in the 1921–22 results.

Considering the total nitrogen results presented in Table No. 43, it is noteworthy that the 1921–22 results do not differ materially from those found in 1901.

TABLE No. 42.—*Nitrogen oxide results—Yearly averages in parts per million*

Station	Year						
	1896	1897	1898	1899	1900	1901	1921-22
265				0.23	0.34	0.33	0.44
263	1.87	1.25	0.96	.56	.82		.73
240				2.35	1.87	1.66	.93
226	2.76	2.58	1.20	2.34	1.85		.99
166		1.94	.93	1.78	1.66	1.42	1.16

---

[3] Chemical Survey of the Waters of Illinois. Report for the years 1897–1902. By Arthur William Palmer, Sc. D. Published by the University of Illinois. 1903.

TABLE No. 43.—*Total nitrogen results—Yearly averages in parts per million*

Station	Year						
	1896	1897	1898	1899	1900	1901	1921-22
285				19.64	4.85	2.78	2.68
263	6.86	6.64	7.36	11.40	4.06		2.65
240				8.45	4.63	2.52	2.64
226	4.99	3.54	3.61	6.16	2.75		2.56
166		2.79	2.63	3.89	3.07	2.79	3.10

As in the case of the total nitrogen results, the 1921–22 oxygen consumed data collected in Table No. 44 bear many points of resemblance to the results of the earlier studies. Logical explanations are lacking, however, for the anomalous increase from station 285 to 240. Likewise, the decrease between stations 226 and 166 appears to be disproportionately great in the case of the 1921–22 results. In a measure these discrepancies are no doubt due to inherent defects in the permanganate oxygen consumed determination. They may also be connected with the difficulty of securing representative samples for analysis.

TABLE No. 44.—*Oxygen consumed results—Yearly averages in parts per million*

Station	Year						
	1896	1897	1898	1899	1900	1901	1921-22
285				28.5	11.1	9.1	8.11
263	14.5	15.9	17.3	14.7	12.3		8.76
240				11.3	8.6	6.6	8.85
226	12.3	18.1	11.2	[1] 13.6	10.1		8.55
166		11.3	9.3	12.9	8.4	7.7	5.67

[1] February to December.

On the whole, it appears that the condition of the river at station 166 has not changed appreciably since 1901. The contributing population, however, has increased enormously, and this conclusion merely indicates that the use of lake water for dilution purposes has kept pace with the increase in population. It does not indicate an accelerated rate of self-purification.

The same conclusions would be reached if, instead of considering the actual parts-per-million content, the quantity units of the constituents in question were to be taken. Thus, using the data given in Table No. 45, the percentage increase in the absolute quantity of total nitrogen from 1900 to 1921 was

$$100\left(\frac{30.63-15.2}{15.2}\right)=101 \text{ per cent}$$

and the corresponding increase in the oxygen consumed content was

$$100\left(\frac{66.51-33.4}{33.4}\right)=99 \text{ per cent.}$$

The percentages of increase of pollution between 1900 and 1921 contributed by Chicago to the Illinois River, as measured by these constituents, are in good agreement.

The corresponding increase in actual population contributing sewage during this period may be taken as another measure of the growing load imposed on the stream. The total actual population sewered to the main drainage canal was in 1921 about 2,830,000. In 1900 the area of Chicago south of Eighty-seventh Street and the sections now drained by the north and south side intercepting sewers did not contribute sewage to the main drainage canal. The population of these areas was at that time 21.2 per cent of the total population of Chicago, so that only approximately 78.8 per cent of this total, or about 1,340,000 persons, then contributed sewage to the Illinois. The increase in the population load from 1900 to January 1, 1922, was then approximately

$$100\left(\frac{2{,}830{,}000-1{,}340{,}000}{1{,}340{,}000}\right)=111 \text{ per cent.}$$

This percentage increase in population is not in close accord with the increase measured by the total nitrogen and oxygen consumed constituents as above developed, and may be partly explained by fluctuations in the amount and nature of industrial wastes during the interval. The total equivalent population estimates would doubtless supply a more reasonable basis of computation. Such estimates have been made for 1921, amounting to a total of 4,720,000 equivalent population, but for 1900 sufficient data are not available to venture a reasonably comparable figure.

The extent of increase in pollution of the river from the period 1896–1899, just prior to the opening of the main drainage canal, to the close of 1921, as indicated by the changes in amounts of total nitrogen and of oxygen consumed, may be estimated in the same way from the data presented in Table No. 45.

TABLE No. 45.—*Quantities of nitrogenous and oxygen-consuming material discharged into the Illinois River at Chicago*

Year	Tons per day [5] at station 292				Quantity units at station 292				References
	Free ammonia A	Organic nitrogen B	Total nitrogen A+B	Oxygen consumed, 30-minute boil	Free ammonia A	Organic nitrogen B	Total nitrogen A+B	Oxygen consumed, 30-minute boil	
1896–1899	21.9	8.6	30.5	64.6	8.1	3.2	11.3	23.9	(1)
1900	28.84	12.23	41.09	90.2	10.7	4.5	15.2	[3] 33.4	(2)
1901	30.23	13.08	43.31	111.3	11.2	4.8	16.0	[3] 41.2	(3)
1921–22	34.4	44.0	82.6	....	12.76	16.29	[6] 30.63	65.51	(4)

---

[1] Chemical Survey of the Waters of the Illinois, 1897-1902, by A. W. Palmer, University of Illinois, 1903, Table III, p. 67.

[2] Ibid., Appendix, p. XV.

[3] Ibid., p. 68, Tables IV and V, and Discharge as on p. 70.

[4] Table No. 30, this report.

[5] Tons per day = (2.7) × (quantity units).

[6] A+B+1.58 as nitrogen oxides.

In this case the increase in total nitrogen is

$$100\left(\frac{30.63-11.3}{11.3}\right)=171 \text{ per cent}$$

or, using the oxygen consumed values of these respective years, the increase is found to be

$$100\left(\frac{66.51-23.9}{23.9}\right)=178 \text{ per cent}$$

The comparison is quite satisfactory in this case, as were the same results for the period 1900–1921. The general conclusion to be drawn is that in 1921 the total volume of pollution contributed by Chicago to the Illinois River was about two and three-fourths times as great as the amount added just prior to the opening of the main drainage canal, and that since the opening of the canal in 1900 this pollution has just about doubled in total volume. However, the amounts of diluting water withdrawn from Lake Michigan have been gradually increased during this interval, so that the net effect has been to actually reduce rather than to increase the total nitrogen and oxygen consumed content as measured in terms of concentration.

CHAPTER VI

BACTERIOLOGICAL STUDIES

As the Illinois River is not used as a source of municipal water supply, the bacteriological studies are of interest principally for such information as they may supply regarding the rates of natural bacterial purification under varying conditions, and especially as an extension of observations previously made upon the Ohio River.

Observations of the bacterial content were made on samples collected daily or triweekly, and consisted of standard plate counts on gelatin incubated at 20° C. for 48 hours and on agar incubated at 37° C. for 24 hours, as well as quantitative tests for *B. coli* by means of fermentation tests in lactose broth in portions of geometric series.

PRESENTATION OF DATA

Since the individual daily analyses comprise a large number of separate observations, the data are presented in the form of tables of arithmetical monthly averages, computed in each case from all the results for each sampling station, for each month. For purposes of ready comparison, these basic data are arranged in tables as follows:

(1) Summary for each station during all months when samples were taken, the means of daily bacteriological observations, as well as mean river discharge, mean water temperature, alkalinity, turbidity, and results of dissolved oxygen determinations. The latter are not discussed in this report, but are inserted here as a matter of record and for future reference.

(2) The same base data as in (1) rearranged and summarized by months in the form of means for each month at all stations.

(3) Summary of monthly means of bacteriological observations at each station in terms of "quantity units" (bacteria per cubic centimeter multiplied by discharge in thousands of second-feet).

(4) Summary of bacteriological observations at all stations in terms of quantity units, grouped by seasonal means of gelatin counts, agar counts, and *B. coli*, respectively.

In Table No. 46 are presented averages for all months of analytical data for each of the 35 sampling stations from which samples were collected. The average discharge and total number of samples composing the average monthly result are also given for purposes of reference. Table No. 47 contains these same basic data grouped to give, for each of the 14 months during which the field studies were carried on, the analytical results at all sampling stations. The average time of flow in hours to each successive sampling station from station 292 is also given. Sampling stations are arranged in consecutive order passing downstream, tributaries being inserted between points where they join the main stream.

TABLE No. 46.—*Summary of bacteriological observations and dissolved oxygen determinations, by stations—Monthly means at each station with corresponding means of discharge and related data*

SAMPLING STATION "SUMMIT"—CHICAGO DRAINAGE CANAL AT SUMMIT, 22 MILES ABOVE LOCKPORT

[Analyses by Sanitary District of Chicago]

Month	Average discharge (second-feet)	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended matter (parts per million)	Bacteria per cubic centimeter: On gelatin at 20° C. 48 hours	On agar at 37° C. 24 hours	B. coli (estimated)	Dissolved oxygen: Initial: Parts per million	Per cent saturation	Loss on incubation for 5 days at 20° C. (parts per million)
1921												
July	8,700	24	24.7							0.22	3.8	18.04
August	8,490	27	21.9	141			2,510,000	2,340,000	29,400	.96	10.7	14.86
September	8,220	25	19.2	136			2,870,000	1,910,000	24,800	1.45	15.6	12.33
October	8,540	31	12.4	130			1,380,000	794,000	31,200	4.45	41.4	9.51
November	8,570	26	8.0	130			1,020,000	225,000	11,200	7.50	63.7	12.80
December	8,670	23	4.2	130			468,000	81,900	8,230	10.42	79.9	15.90
1922												
January	8,310	29	1.2	130			181,000	58,500	3,580	11.16	78.9	17.78
February	8,280	28	2.0	126			196,000	46,100	1,380	11.70	84.5	19.34
March	8,740	31	4.9	130			207,000	22,200	2,520	10.50	80.7	22.60
April	8,480	29	8.2	131			912,000	82,900	3,500	7.88	66.7	12.98
May	8,910	31	14.5	128			1,480,000	167,000	12,200	5.20	50.6	16.27
June	9,370	30	19.7	128			1,820,000	719,000	26,300	2.44	26.4	16.66
July	8,850	31	22.1	128			1,870,000	1,180,000	21,800	1.54	17.5	14.07
August	8,820	31	23.1	129			2,160,000	1,470,000	20,500	1.34	15.5	15.20

SAMPLING STATION 99—CHICAGO DRAINAGE CANAL AT LOCKPORT, 1 MILE ABOVE POWER PLANT

Month	Average discharge (second-feet)	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended matter (parts per million)	Bacteria per cubic centimeter: On gelatin at 20° C. 48 hours	On agar at 37° C. 24 hours	B. coli (estimated)	Dissolved oxygen: Initial: Parts per million	Per cent saturation	Loss on incubation for 5 days at 20° C. (parts per million)
1921												
August	8,460	27	22.7	131	34		2,080,000	3,160,000	36,700	0.08	0.9	14.07
September	8,290	24	20.1	129	32	18.2	3,420,000	4,290,000	29,600	.01	.1	15.16
October	8,540	25	12.9	128	28	23.8	2,900,000	2,270,000	20,500	.94	9.0	13.14
November	8,870	23	7.4	121	48	30.1	867,000	467,000	10,400	4.27	36.2	12.28
December	8,670	25	3.2	118	78	61.9	694,000	230,000	9,210	7.64	57.0	16.30
1922												
January	8,310	24	.3	121	42	20.6	610,000	86,400	3,850	9.75	67.2	20.72
February	8,280	21	1.0	120	35	24.3	667,000	81,900	5,200	9.11	64.0	23.40
March	8,740	26	3.7	122	46	27.4	207,000	68,600	4,060	7.86	59.5	19.56
April	8,480	28	8.6	115	47	29.1	1,260,000	186,000	10,400	2.88	22.7	9.75
May	8,910	26	15.6	120	34	26.8	2,240,000	891,000	40,500	.41	4.0	12.42
June	9,370	25	20.9	124	26	35.6	2,860,000	1,800,000	56,800	.08	.8	14.60
July	8,850	24	22.4	124	20	29.3	3,780,000	2,840,000	118,000	.01	.1	11.20
August	8,590	26	23.8	124	22	24.7	3,800,000	3,980,000	24,500	.01	.1	11.98

SAMPLING STATION DES PLAINES—DES PLAINES RIVER AT LEMONT, 11 MILES ABOVE JUNCTION WITH MAIN DRAINAGE CANAL

Month	Average discharge (second-feet)	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended matter (parts per million)	Bacteria per cubic centimeter: On gelatin at 20° C. 48 hours	On agar at 37° C. 24 hours	B. coli (estimated)	Dissolved oxygen: Initial: Parts per million	Per cent saturation	Loss on incubation for 5 days at 20° C. (parts per million)
1921												
August	11	27	21.9	161	5		128,000	151,000	1,000	8.55	96.6	2.53
September	44	24	19.8	173	4		214,000	247,000	4,820	9.21	100.0	4.61
October	198	25	10.8	189	55		8,680	3,110	21	6.89	61.9	3.30
November	395	22	4.5	175	32		11,700	12,200	224	10.05	77.4	3.08
December	1,610	24	1.2	161	71		31,300	17,000	265	11.89	85.5	3.27
1922												
January	498	24	.0	212	19		33,700	12,900	187	8.62	59.0	3.29
February	121	18	.2	224	32		71,700	28,600	21	6.18	42.8	4.22
March	1,030	26	3.1	118	149		187,000	86,000	173	9.82	73.1	4.58
April	1,600	23	9.6	163	87		22,900	4,900	95	8.93	77.0	2.33
May	251	25	18.2	222	40		5,210	1,310	16	8.26	88.0	5.55
June	66	24	22.1	206	55		2,900	2,360	17	5.90	67.0	6.24
July	40	24	22.9	212	50		7,580	10,300	14	6.20	73.0	7.34
August	33	26	22.9	191	51		8,440	11,300	4	4.15	47.5	5.29

Table No. 46.—*Summary of bacteriological observations and dissolved oxygen determinations, by stations—Monthly means at each station with corresponding means of discharge and related data*—Continued

SAMPLING STATION 288.7-288.1—DES PLAINES RIVER AT JOLIET, IMMEDIATELY BELOW JUNCTION WITH MAIN DRAINAGE CANAL

Month	Average discharge (second-feet)	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	Bacteria per cubic centimeter: On gelatin at 20° C. 48 hours	Bacteria per cubic centimeter: On agar at 37° C. 24 hours	Bacteria per cubic centimeter: B. coli (estimated)	Dissolved oxygen: Initial: Parts per million	Dissolved oxygen: Initial: Per cent saturation	Dissolved oxygen: Loss on incubation for 5 days at 20° C. (parts per million)
1921												
August	8,270	27	22.7	130	36	......	1,590,000	2,220,000	40,300	0.20	2.3	12.84
September	8,080	24	20.4	129	32	......	2,530,000	2,720,000	48,400	.38	4.2	12.06
October	8,780	25	13.7	130	33	......	1,750,000	1,320,000	23,300	1.79	17.1	12.90
November	9,750	24	6.8	140	43	......	402,000	264,000	4,600	6.36	52.0	11.57
December	10,400	26	3.4	123	80	......	613,000	235,000	7,900	7.81	58.6	16.45
1922												
January	8,700	24	.8	123	45	......	681,000	125,000	2,590	9.57	67.0	20.89
February	8,330	21	.6	122	38	......	717,000	123,000	3,130	9.02	62.7	24.52
March	9,780	27	(4.0)	122	56	......	408,000	94,700	3,570	7.72	58.8	20.10
April	10,200	25	(8.9)	124	82	......	1,140,000	155,000	8,130	5.02	43.4	11.46
May	9,010	26	(15.4)	121	28	......	1,800,000	318,000	18,200	......	......	......
June	9,250	15	21.5	122	29	......	2,280,000	1,390,000	36,300	......	......	......

SAMPLING STATIONS 287.9-287.3—DES PLAINES RIVER AT JOLIET

Month	Average discharge (second-feet)	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	Bacteria per cubic centimeter: On gelatin at 20° C. 48 hours	Bacteria per cubic centimeter: On agar at 37° C. 24 hours	Bacteria per cubic centimeter: B. coli (estimated)	Dissolved oxygen: Initial: Parts per million	Dissolved oxygen: Initial: Per cent saturation	Dissolved oxygen: Loss on incubation for 5 days at 20° C. (parts per million)
1921												
August	8,270	27	22.9	130	38	......	1,930,000	2,110,000	40,900	0.86	9.9	12.68
September	8,080	24	20.4	129	32	......	2,510,000	3,070,000	50,500	.56	6.2	12.73
October	8,780	25	13.9	124	31	......	2,030,000	1,620,000	41,000	1.74	16.9	13.00
November	9,750	23	7.2	125	47	......	621,000	371,000	13,900	5.11	42.2	12.10
December	10,400	25	3.1	123	81	......	631,000	274,000	7,660	8.21	61.1	14.78
1922												
January	8,700	24	.3	123	46	......	594,000	105,000	3,130	10.12	69.9	19.75
February	8,330	21	1.1	122	37	......	812,000	100,000	4,250	9.22	65.0	24.38
March	9,780	26	4.0	122	53	......	618,000	84,000	3,080	7.82	59.5	20.49
April	10,200	24	8.9	127	74	......	1,370,000	221,000	9,600	4.62	39.8	12.85
May	9,010	25	15.4	124	30	......	1,800,000	341,000	26,200	......	......	......
June	9,250	14	20.2	124	29	......	2,410,000	1,490,000	51,500	......	......	......

SAMPLING STATION 288—DES PLAINES RIVER AT JOLIET

(Average of results of stations 288.7-288.1 and 287.9-287.3)

Month	Average discharge (second-feet)	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	Bacteria per cubic centimeter: On gelatin at 20° C. 48 hours	Bacteria per cubic centimeter: On agar at 37° C. 24 hours	Bacteria per cubic centimeter: B. coli (estimated)	Dissolved oxygen: Initial: Parts per million	Dissolved oxygen: Initial: Per cent saturation	Dissolved oxygen: Loss on incubation for 5 days at 20° C. (parts per million)
1921												
August	8,270	27	22.8	130	37	......	1,760,000	2,170,000	40,600	0.53	6.1	12.76
September	8,080	24	20.4	129	32	......	2,520,000	2,900,000	49,500	.47	5.2	12.40
October	8,780	25	13.8	127	32	......	1,890,000	1,470,000	32,200	1.77	17.0	12.95
November	9,750	24	7.0	133	45	......	512,000	318,000	9,250	5.74	47.2	11.84
December	10,400	25	3.3	123	81	......	622,000	254,000	7,780	8.01	60.0	15.62
1922												
January	8,700	24	.6	123	46	......	638,000	115,000	2,860	9.85	68.5	20.32
February	8,330	21	.9	122	38	......	764,000	112,000	3,690	9.12	64.0	24.45
March	9,780	26	4.0	122	55	......	513,000	89,400	3,320	7.77	59.1	20.30
April	10,200	24	8.9	126	78	......	1,260,000	188,000	8,860	4.82	41.6	12.16
May	9,010	25	15.4	123	29	......	1,800,000	330,000	22,200	......	......	......
June	9,250	15	20.9	123	29	......	2,340,000	1,440,000	43,900	......	......	......

TABLE No. 46.—*Summary of bacteriological observations and dissolved oxygen determinations, by stations—Monthly means at each station with corresponding means of discharge and related data*—Continued

SAMPLING STATION 286—DES PLAINES RIVER AT BRANDON BRIDGE, 285.8 MILES ABOVE GRAFTON, IMMEDIATELY BELOW JOLIET

Month	Average discharge (second-feet)	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	Bacteria per cubic centimeter			Dissolved oxygen		
							On gelatin at 20° C. 48 hours	On agar at 37° C. 24 hours	B. coli (estimated)	Initial		Loss on incubation for 5 days at 20° C. (parts per million)
										Parts per million	Per cent saturation	
1921												
August	8,270	27	23.0	128	31	46.5	958,000	1,470,000	24,700	1.40	16.1	11.70
September	8,980	28	20.1	128	30	34.6	2,080,000	2,370,000	31,800	1.07	11.7	12.03
October	8,770	25	13.7	126	37	39.8	1,080,000	1,280,000	46,300	3.01	28.9	12.47
November	9,780	25	6.9	127	48	52.6	838,000	282,000	9,450	6.51	58.3	13.16
December	10,400	24	2.1	137	70	65.2	880,000	219,000	7,110	9.35	68.5	13.05
1922												
January	8,780	24	.8	125	42	36.9	640,000	86,000	3,420	11.01	77.0	13.97
February	[illegible]	21	1.8	122	36	32.9	682,000	117,000	2,160	10.12	72.0	23.48
March	9,780	25	4.6	123	55	54.7	884,000	130,000	2,680	8.96	69.3	19.67
April	10,200	24	9.4	129	75	64.9	1,190,000	180,000	3,900	6.08	53.5	12.86
May	9,010	25	15.0	130	31	45.1	1,380,000	288,000	14,100	2.89	28.5	14.37
June	9,290	25	20.5	125	29	38.9	1,370,000	981,000	38,100	1.82	20.0	12.94
July	8,700	24	22.6	123	27	46.9	1,780,000	1,810,000	19,400	1.40	16.7	7.10
August	8,380	26	22.7	128	19	30.3	1,770,000	2,160,000	22,500	1.28	15.1	7.48

SAMPLING STATION 278—DES PLAINES RIVER AT CHANNAHON, 277.6 MILES ABOVE GRAFTON AND 4.6 MILES ABOVE JUNCTION WITH KANKAKEE

Month	Average discharge (second-feet)	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	On gelatin at 20° C. 48 hours	On agar at 37° C. 24 hours	B. coli (estimated)	Parts per million	Per cent saturation	Loss on incubation for 5 days at 20° C. (parts per million)
1921												
October	8,810	5	------	135	37	------	643,000	800,000	------	1.86	------	14.75
November	9,780	12	7.2	127	48	------	458,000	185,000	4,680	6.49	53.5	10.86
December	10,600	11	4.0	137	79	------	341,000	126,000	3,370	8.48	64.6	10.44
1922												
January	8,730	12	1.6	127	40	------	808,000	70,000	3,160	10.42	74.5	15.38
February	8,250	9	2.4	134	40	------	971,000	74,800	3,800	8.34	60.9	23.73
March	9,820	12	4.4	124	52	------	868,000	96,200	1,440	7.77	59.7	17.38
April	10,400	9	[1] (9.4)	124	88	------	1,190,000	133,000	3,900	4.79	37.3	12.68
May	9,070	14	[1] (15.0)	128	29	------	1,162,000	128,000	11,200	1.12	11.0	14.77
June	9,290	12	[1] (20.5)	134	27	------	1,040,000	780,000	15,700	.12	1.3	12.46
July	8,730	13	22.9	126	26	------	1,610,000	1,770,000	21,800	.22	2.5	10.96
August	8,990	13	25.6	123	21	------	1,400,000	1,740,000	7,750	.23	2.8	7.94

SAMPLING STATION KANKAKEE—KANKAKEE RIVER AT WILMINGTON, 10 MILES ABOVE THE MOUTH

Month	Average discharge (second-feet)	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	On gelatin at 20° C. 48 hours	On agar at 37° C. 24 hours	B. coli (estimated)	Parts per million	Per cent saturation	Loss on incubation for 5 days at 20° C. (parts per million)
1921												
August	706	22	23.6	156	16	------	1,660	1,650	8	7.90	88.8	1.25
September	1,280	22	23.3	159	43	------	6,200	4,530	32	7.65	88.6	1.89
October	1,120	24	13.2	157	20	------	1,430	1,450	28	10.09	95.5	2.34
November	4,840	23	7.3	169	65	------	5,300	5,190	40	11.65	95.5	2.73
December	5,900	25	4.0	164	31	------	8,120	3,880	131	11.93	90.9	2.20
1922												
January	4,880	24	1.1	184	24	------	19,400	7,770	30	12.93	91.1	2.48
February	3,870	21	1.6	182	75	------	45,200	9,970	123	11.39	82.8	2.49
March	9,200	25	5.0	146	225	------	22,400	7,430	38	10.93	85.4	2.70
April	19,600	24	10.7	108	340	------	21,500	6,690	60	8.96	79.8	2.85
May	5,160	25	19.7	171	80	------	8,400	2,780	17	7.66	83.2	1.45
June	1,020	24	24.5	190	35	------	4,030	3,560	73	7.30	88.4	1.16
July	1,020	20	24.9	168	20	------	9,400	5,270	12	7.08	84.5	1.60
August	712	25	24.5	164	19	------	8,800	7,270	3	6.50	76.9	.91

---

[1] Assumed same as for station 285.8.

TABLE No. 46.—*Summary of bacteriological observations and dissolved oxygen determinations, by stations—Monthly means at each station with corresponding means of discharge and related data*—Continued

SAMPLING STATION 263—ILLINOIS RIVER AT MORRIS, 263.2 MILES ABOVE GRAFTON

Month	Average discharge (second-feet)	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	Bacteria per cubic centimeter			Dissolved oxygen		
							On gelatin at 20° C. 48 hours	On agar at 37° C. 24 hours	B. coli (estimated)	Initial		Loss on incubation for 5 days at 20° C. (parts per million)
										Parts per million	Per cent saturation	
1921												
August	9,720	25	22.1	134	23	44.7	----------	529,000	8,520	0.57	4.6	8.07
September	9,930	26	21.0	127	26	58.2	----------	2,370,000	31,600	.20	2.1	12.74
October	10,800	25	12.5	129	26	48.6	414,000	286,000	11,800	1.43	13.6	12.65
November	15,200	23	7.6	131	53	66.6	469,000	251,000	6,[illegible]	5.42	46.2	11.80
December	17,900	24	3.7	130	77	61.3	526,000	290,000	3,710	8.26	63.4	10.92
1922												
January	14,000	24	1.1	135	57	42.5	701,000	97,100	2,710	9.32	65.6	17.85
February	12,300	21	1.8	122	59	46.5	800,000	100,000	2,190	7.72	55.5	28.59
March	19,900	24	4.7	122	154	98.8	695,000	110,000	2,820	7.29	57.2	12.02
April	32,300	24	10.3	119	272	164.0	309,000	37,900	1,640	7.26	65.2	5.20
May	15,200	25	16.2	141	47	60.2	317,000	84,900	6,190	1.91	19.2	9.46
June	11,900	25	20.6	136	42	63.8	1,120,000	965,000	26,800	.26	2.9	18.02
July	10,300	24	22.7	129	29	47.1	794,000	712,000	12,[illegible]	.16	1.7	6.88
August	9,080	24	23.5	129	20	37.7	888,000	971,000	10,[illegible]	.16	1.9	7.22

SAMPLING STATION 247—ILLINOIS RIVER IMMEDIATELY ABOVE DAM AT MARSEILLES, 247.2 MILES ABOVE GRAFTON

Month	Average discharge (second-feet)	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	On gelatin at 20° C. 48 hours	On agar at 37° C. 24 hours	B. coli (estimated)	Parts per million	Per cent saturation	Loss on incubation for 5 days at 20° C. (parts per million)
1922												
May	15,400	17	16.7	140	46	......	66,800	28,000	857	1.97	20.1	8.52
June	11,900	22	21.0	136	35	......	240,000	216,000	7,200	.43	4.8	7.53
July	10,400	22	22.1	132	29	......	985,000	875,000	10,900	.25	2.6	7.65
August	9,670	25	22.3	126	21	......	1,040,000	1,040,000	10,400	.09	1.0	7.41

SAMPLING STATION 240—ILLINOIS RIVER, 240.9 MILES ABOVE GRAFTON, IMMEDIATELY ABOVE JUNCTION OF FOX RIVER, AND ABOVE CITY OF OTTAWA

Month	Average discharge (second-feet)	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	On gelatin at 20° C. 48 hours	On agar at 37° C. 24 hours	B. coli (estimated)	Parts per million	Per cent saturation	Loss on incubation for 5 days at 20° C. (parts per million)
1921												
July	9,220	24	26.1	115	27	......	726,000	582,000	12,600	0.56	6.7	11.12
August	9,280	25	24.0	126	30	......	432,000	465,000	3,770	1.44	16.9	8.00
September	10,000	20	21.7	124	45	......	290,000	352,000	3,970	1.79	20.2	6.60
October	10,000	18	14.0	131	45	......	214,000	140,000	2,900	3.26	31.5	7.91
November	15,300	17	6.1	137	65	......	246,000	71,400	1,[illegible]	6.82	54.8	6.03
December	18,100	23	2.6	146	70	......	231,000	37,000	1,900	9.74	71.5	6.28
1922												
January	14,100	17	.5	136	73	......	375,000	32,300	1,880	10.41	72.2	10.70
February	12,800	21	0	142	86	......	261,000	26,700	1,310	8.12	55.5	10.96
March	20,100	26	3.2	141	118	......	306,000	28,800	1,310	9.08	67.5	9.30
April	34,000	16	9.2	126	318	......	184,000	31,200	1,220	8.08	70.0	6.11
May	15,400	23	[1] (17.0)	146	42	......	79,000	28,500	1,070	3.41	35.0	8.38
June	11,900	24	21.3	136	43	......	412,000	347,000	7,480	1.32	14.8	9.29
July	10,400	22	24.0	132	30	......	712,000	584,000	14,300	.40	5.7	8.83
August	9,670	25	22.4	129	26	......	727,000	501,000	9,000	.32	3.7	8.68

[1] Average of temperatures at stations 247.2 and 238.8.

TABLE No. 46.—*Summary of bacteriological observations and dissolved oxygen determinations, by stations—Monthly means at each station with corresponding means of discharge and related data*—Continued

SAMPLING STATION FOX—FOX RIVER AT MOUTH, IMMEDIATELY ABOVE CITY OF OTTAWA

Month	Average discharge (second-feet)	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	Bacteria per cubic centimeter: On gelatin at 20° C. 48 hours	On agar at 37° C. 24 hours	B. coli (estimated)	Dissolved oxygen: Initial: Parts per million	Per cent saturation	Loss on incubation for 5 days at 20° C. (parts per million)
1921												
July	[illegible]	[illegible]	25.6	195	16	......	15,400	3,940	115	7.06	90.1	1.95
August	[illegible]	[illegible]	24.0	180	[illegible]	......	22,[illegible]	14,700	94	7.9[illegible]	92.2	1.67
September	[illegible]	20	21.7	[illegible]	[illegible]	......	17,400	17,[illegible]	27	7.8[illegible]	[illegible]	2.01
October	1,[illegible]	17	13.8	216	[illegible]	......	11,800	6,[illegible]	26	9.6[illegible]	[illegible]	1.77
November	2,170	17	4.7	224	[illegible]	......	8,910	2,460	121	11.2[illegible]	[illegible]	2.02
December	3,[illegible]	22	1.9	212	44	......	17,[illegible]	6,[illegible]	215	12.46	[illegible]	2.13
1922												
January	3,[illegible]	17	.5	[illegible]	[illegible]	......	28,100	4,720	167	12.2[illegible]	88.2	2.89
February	1,[illegible]	[illegible]	.0	[illegible]	[illegible]	......	31,650	2,700	10	11.51	73.7	2.40
March	2,[illegible]	[illegible]	3.4	102	[illegible]	......	108,000	10,800	130	11.0[illegible]	87.1	4.5[illegible]
April	4,[illegible]	[illegible]	8.0	[illegible]	[illegible]	......	14,[illegible]	3,[illegible]	[illegible]	9.5[illegible]	82.7	3.0[illegible]
May	1,[illegible]	[illegible]	15.6	[illegible]	1[illegible]	......	6,[illegible]	2,[illegible]	[illegible]	7.9[illegible]	77.2	1.97
June	[illegible]	[illegible]	22.1	[illegible]	[illegible]	......	8,[illegible]	11,[illegible]	9	7.0[illegible]	81.[illegible]	.9[illegible]
July	221	[illegible]	24.7	[illegible]	12	......	9,[illegible]	8,[illegible]	21	7.0[illegible]	82.7	1.14
August	237	[illegible]	22.4	[illegible]	2	......	102,000	88,000	4,870	6.11	70.9	1.42

SAMPLING STATION 227.—ILLINOIS RIVER, 226.8 MILES ABOVE GRAFTON, IMMEDIATELY ABOVE JUNCTION OF VERMILION RIVER AND ABOVE CITY OF LA SALLE

Month	Average discharge (second-feet)	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	Bacteria per cubic centimeter: On gelatin at 20° C. 48 hours	On agar at 37° C. 24 hours	B. coli (estimated)	Dissolved oxygen: Initial: Parts per million	Per cent saturation	Loss on incubation for 5 days at 20° C. (parts per million)
1921												
July	9,[illegible]	26	26.3	135	26	......	157,000	110,000	5,700	0.77	8.8	6.98
August	9,4[illegible]	19	23.4	137	13	......	96,300	72,500	1,190	1.15	12.[illegible]	4.47
September	10,9[illegible]	23	20.9	137	23	......	67,300	73,500	1,470	1.8[illegible]	17.8	5.33
October	12,3[illegible]	18	13.4	145	22	......	108,000	69,300	1,230	3.0[illegible]	29.4	6.73
November	17,000	19	6.4	145	22	......	202,000	58,000	1,810	6.34	51.2	6.71
December	21,900	19	2.3	130	57	......	338,000	36,900	1,810	9.78	71.0	6.68
1922												
January	16,900	20	.4	155	42	......	275,000	24,200	1,000	10.15	70.2	6.40
February	14,6[illegible]	18	.9	146	62	......	361,000	26,800	2,700	9.24	64.8	9.16
March	26,100	25	4.8	141	158	......	442,000	57,800	2,940	8.94	69.5	8.73
April	30,000	23	10.1	120	197	......	87,100	14,800	780	7.90	69.9	2.77
May	17,000	23	17.2	148	96	......	55,800	19,400	560	3.20	32.9	7.80
June	12,000	23	21.2	148	35	......	108,000	65,700	3,000	.53	6.3	8.10
July	10,900	24	22.9	124	45	......	152,000	142,000	2,640	.06	7.6	6.19
August	10,600	22	23.7	131	31	......	200,000	94,700	3,370	.45	5.3	5.46

SAMPLING STATION VERMILION—VERMILION RIVER AT MOUTH

Month	Average discharge (second-feet)	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	Bacteria per cubic centimeter: On gelatin at 20° C. 48 hours	On agar at 37° C. 24 hours	B. coli (estimated)	Dissolved oxygen: Initial: Parts per million	Per cent saturation	Loss on incubation for 5 days at 20° C. (parts per million)
1921												
July	9	26	23.4	144	72	......	23,200	19,500	117	5.44	69.2	2.28
August	3	19	24.4	122	46	......	10,200	14,000	37	5.70	67.3	2.73
September	290	23	21.8	129	126	......	27,000	24,700	105	7.01	78.0	2.29
October	197	19	15.6	191	87	......	9,400	3,000	290	8.78	86.2	1.53
November	1,020	19	7.1	206	84	......	24,600	8,680	194	10.3[illegible]	85.6	2.40
December	1,270	19	2.8	206	91	......	22,100	6,810	116	12.0[illegible]	88.7	2.36
1922												
January	443	18	.5	222	95	......	37,800	6,270	204	12.75	88.4	2.09
February	708	18	.9	162	215	......	176,000	19,500	224	11.72	82.2	2.09
March	2,600	25	4.7	177	480	......	37,200	11,900	209	11.26	87.3	2.17
April	4,300	22	10.2	150	555	......	25,800	7,080	170	9.58	84.4	1.08
May	775	23	19.3	199	45	......	5,000	1,600	37	8.13	87.5	1.04
June	189	23	24.9	198	64	......	15,400	8,900	84	6.22	74.1	1.16
July	58	24	25.6	154	110	......	11,300	7,430	73	5.84	70.4	1.34
August	1	22	24.8	120	82	......	10,400	9,870	177	6.10	72.5	2.06

TABLE No. 46.—*Summary of bacteriological observations and dissolved oxygen determinations, by stations—Monthly means at each station with corresponding means of discharge and related data*—Continued

SAMPLING STATION 196—ILLINOIS RIVER 196 MILES ABOVE GRAFTON, AT TOWN OF HENRY

Month	Average discharge (second-feet)	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	Bacteria per cubic centimeter: On gelatin at 20° C. 48 hours	Bacteria per cubic centimeter: On agar at 37° C. 24 hours	Bacteria per cubic centimeter: B. coli (estimated)	Dissolved oxygen: Initial: Parts per million	Dissolved oxygen: Initial: Per cent saturation	Dissolved oxygen: Loss on incubation for 5 days at 20° C. (parts per million)
1921												
July	9,880	26	27.7	138	[illegible]	......	73,800	34,900	222	0.69	8.7	3.34
August	9,730	27	24.2	157	[illegible]	......	95,400	35,900	257	1.11	13.1	3.19
September	11,800	24	21.6	136	49	......	21,700	23,300	182	2.46	27.6	3.88
October	12,670	25	13.0	148	[illegible]	......	15,600	13,700	147	5.30	50.9	4.38
November	17,800	23	7.3	159	77	......	48,300	12,200	276	8.51	70.8	4.80
December	24,000	25	2.9	162	22	......	35,100	3,650	139	11.69	81.8	4.20
1922												
January	15,200	18	.9	160	14	......	95,300	4,990	215	8.94	62.8	6.32
February	15,200	22	1.2	152	31	......	165,000	7,840	220	8.65	61.1	3.67
March	26,100	22	4.5	144	97	......	96,200	7,790	234	9.46	72.6	7.56
April	45,700	24	10.4	133	108	......	16,700	2,160	71	8.86	78.1	4.73
May	20,200	27	18.6	155	38	......	18,200	6,120	82	5.11	60.7	5.38
June	14,400	25	23.5	146	45	......	27,300	22,700	[illegible]	2.60	31.2	8.88
July	11,320	24	24.2	137	80	......	58,900	71,100	[illegible]	1.02	12.6	4.94
August	10,100	25	25.1	136	64	......	192,000	126,000	487	.95	11.3	7.97

SAMPLING STATION 170—ILLINOIS RIVER 170 MILES ABOVE GRAFTON, AT TOWN OF CHILLICOTHE AND HEAD OF PEORIA LAKE

Month	Average discharge (second-feet)	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	Bacteria per cubic centimeter: On gelatin at 20° C. 48 hours	Bacteria per cubic centimeter: On agar at 37° C. 24 hours	Bacteria per cubic centimeter: B. coli (estimated)	Dissolved oxygen: Initial: Parts per million	Dissolved oxygen: Initial: Per cent saturation	Dissolved oxygen: Loss on incubation for 5 days at 20° C. (parts per million)
1921												
July	10,000	26	27.6	138	22	......	62,300	44,100	1,400	1.12	14.0	4.21
August	9,880	27	22.8	140	27	22.6	16,800	20,000	81	1.23	14.4	3.34
September	11,700	24	21.4	138	30	25.2	13,900	12,100	121	1.30	14.6	4.80
October	12,880	25	13.2	147	34	22.7	9,700	6,200	84	3.95	37.4	3.66
November	16,600	22	7.5	152	63	45.2	21,400	5,820	204	7.18	59.7	2.76
December	24,680	24	3.9	150	22	37.1	37,300	3,120	97	10.10	76.9	2.96
1922												
January	10,800	22	.1	161	17	19.2	93,800	2,760	[illegible]	8.16	55.0	3.20
February	15,600	22	.5	152	20	22.6	102,000	2,140	[illegible]	7.79	54.0	2.79
March	25,700	[illegible]	4.4	142	76	59.2	65,800	4,400	136	8.11	70.0	2.85
April	46,700	[illegible]	10.3	133	109	60.8	12,800	1,610	37	8.11	72.1	2.08
May	22,600	[illegible]	18.4	155	65	44.6	3,710	1,290	18	4.60	51.7	2.99
June	15,900	[illegible]	23.5	147	33	30.1	3,090	3,030	73	2.38	28.3	2.94
July	11,430	24	26.6	149	7	14.4	8,710	12,800	201	.79	9.4	2.95
August	10,100	27	24.5	137	16	15.9	50,000	55,700	166	.37	4.4	2.47

SAMPLING STATION 166—ILLINOIS RIVER 166.1 MILES ABOVE GRAFTON, IMMEDIATELY ABOVE CITY OF PEORIA AND AT OUTLET OF PEORIA LAKE

Month	Average discharge (second-feet)	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	Bacteria per cubic centimeter: On gelatin at 20° C. 48 hours	Bacteria per cubic centimeter: On agar at 37° C. 24 hours	Bacteria per cubic centimeter: B. coli (estimated)	Dissolved oxygen: Initial: Parts per million	Dissolved oxygen: Initial: Per cent saturation	Dissolved oxygen: Loss on incubation for 5 days at 20° C. (parts per million)
1921												
July	10,100	25	28.3	139	39	......	5,350	3,420	5	4.78	60.8	2.09
August	9,980	27	24.0	126	45	37.2	2,470	1,100	11	5.05	59.2	2.26
September	11,800	25	22.0	135	67	55.0	3,310	2,080	12	5.25	60.6	2.14
October	12,880	25	12.2	145	38	24.5	1,920	960	18	7.77	73.6	2.40
November	16,100	24	8.0	149	60	23.7	13,900	2,200	60	9.22	77.8	2.25
December	24,900	26	3.9	159	27	21.9	20,900	1,620	55	11.04	84.1	2.81
1922												
January	20,100	25	.2	162	30	21.9	42,300	1,450	140	8.52	58.7	2.68
February	15,800	22	.9	154	21	19.3	33,800	847	59	7.77	54.5	2.22
March	23,100	27	5.5	144	55	37.8	23,900	1,700	20	10.25	81.1	2.40
April	47,200	25	11.2	122	71	35.9	6,050	1,080	13	8.70	79.4	1.68
May	23,600	26	19.2	152	33	22.1	1,730	767	12	7.04	75.5	2.72
June	16,800	26	24.2	145	31	28.9	2,500	1,900	[illegible]	5.89	69.4	5.16
July	11,800	25	24.8	137	58	37.7	7,910	3,500	20	5.06	67.4	5.28
August	10,100	27	24.7	133	46	22.8	6,120	4,400	19	5.06	67.1	5.44

TABLE No. 46.—*Summary of bacteriological observations and dissolved oxygen determinations, by stations—Monthly means at each station with corresponding means of discharge and related data*—Continued

SAMPLING STATION 152—ILLINOIS RIVER 152.4 MILES ABOVE GRAFTON AND IMMEDIATELY ABOVE CITY OF PEKIN

Month	Average discharge (second-feet)	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	Bacteria per cubic centimeter: On gelatin at 20° C. 48 hours	Bacteria per cubic centimeter: On agar at 37° C. 24 hours	Bacteria per cubic centimeter: B. coli (estimated)	Dissolved oxygen: Initial: Parts per million	Dissolved oxygen: Initial: Per cent saturation	Dissolved oxygen: Loss on incubation for 5 days at 20° C. (parts per million)
1921												
July	10,100	26	28.3	140	66	......	43,600	26,900	222	3.68	46.8	3.61
August	10,000	27	24.6	127	65	......	31,300	34,200	360	4.66	54.9	3.36
September	11,900	24	22.5	133	74	......	47,000	30,200	310	4.61	53.6	2.37
October	12,900	25	14.5	144	42	......	28,600	82,000	300	7.60	74.5	4.14
November	16,100	23	7.6	150	47	......	22,200	24,100	130	9.42	78.6	4.00
December	26,100	25	4.2	159	41	......	19,700	4,600	36	11.60	84.2	3.22
1922												
January	20,800	24	.6	164	37	......	45,000	8,250	144	8.94	62.2	3.18
February	16,100	22	.4	155	34	......	41,400	22,100	234	8.46	65.2	4.60
March	28,400	22	4.9	143	73	......	29,000	16,200	507	10.51	81.7	3.56
April	47,800	22	9.6	134	73	......	10,300	2,320	27	8.95	78.3	1.97
May	24,400	25	18.6	144	55	......	22,800	37,500	370	7.19	76.3	4.19
June	16,900	22	24.6	146	52	......	60,100	129,000	1,050	6.60	71.3	6.01
July	11,700	24	25.8	137	81	......	28,800	66,600	251	6.17	74.7	6.60
August	10,100	25	25.5	135	46	......	33,000	50,200	150	5.15	62.1	6.16

SAMPLING STATION 148—ILLINOIS RIVER 147.9 MILES ABOVE GRAFTON AND IMMEDIATELY ABOVE JUNCTION OF MACKINAW RIVER

Month	Average discharge (second-feet)	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	Bacteria per cubic centimeter: On gelatin at 20° C. 48 hours	Bacteria per cubic centimeter: On agar at 37° C. 24 hours	Bacteria per cubic centimeter: B. coli (estimated)	Dissolved oxygen: Initial: Parts per million	Dissolved oxygen: Initial: Per cent saturation	Dissolved oxygen: Loss on incubation for 5 days at 20° C. (parts per million)
1921												
July	10,200	25	28.4	139	112	......	369,000	245,000	4,280	3.67	46.7	4.29
August	10,000	27	24.4	139	90	......	159,000	206,000	1,570	4.49	55.0	4.57
September	11,900	24	22.9	134	111	......	225,000	214,000	2,070	4.50	51.8	3.38
October	12,900	25	14.0	143	43	......	22,300	42,300	380	7.30	71.3	4.80
November	16,200	23	7.4	150	55	......	22,900	18,600	165	9.27	76.9	4.63
December	25,200	24	2.8	160	31	......	15,700	4,770	96	10.84	82.1	3.73
1922												
January	20,600	12	1.0	161	52	......	......	3,300	342	9.62	67.7	2.16
February	16,100	18	.5	154	37	......	28,200	18,200	222	8.70	68.9	5.52
March	28,800	22	4.9	146	70	......	30,100	11,300	191	10.26	80.7	4.42
April	48,000	21	9.6	132	84	......	12,700	2,670	110	8.94	77.3	2.13
May	24,600	25	18.5	142	[illegible]	......	57,100	30,100	220	7.05	74.7	4.44
June	17,000	23	24.8	146	[illegible]	......	174,000	200,000	3,050	6.00	71.4	6.55
July	11,700	24	25.8	139	107	......	208,000	252,000	2,040	7.15	86.6	7.37
August	10,100	26	25.4	135	53	......	314,000	310,000	9,340	6.60	79.2	7.74

SAMPLING STATION MACKINAW—MACKINAW RIVER AT MOUTH

Month	Average discharge (second-feet)	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	Bacteria per cubic centimeter: On gelatin at 20° C. 48 hours	Bacteria per cubic centimeter: On agar at 37° C. 24 hours	Bacteria per cubic centimeter: B. coli (estimated)	Dissolved oxygen: Initial: Parts per million	Dissolved oxygen: Initial: Per cent saturation	Dissolved oxygen: Loss on incubation for 5 days at 20° C. (parts per million)
1921												
July	104	25	25.2	229	112	......	34,600	23,300	25	7.94	95.1	3.31
August	206	27	22.6	191	613	......	67,900	43,600	115	7.73	88.4	2.44
September	830	24	21.0	200	266	......	48,300	34,900	402	7.80	88.4	1.88
October	295	25	13.3	247	80	......	25,200	9,520	161	9.21	87.5	1.48
November	822	23	7.2	228	122	......	27,100	10,600	34	10.55	87.1	2.76
December	1,140	23	4.2	223	147	......	38,100	4,980	120	11.58	88.2	2.62
1922												
January	625	8	1.7	216	745	......	37,100	10,100	100	11.54	82.7	2.07
February	618	11	.7	213	238	......	161,000	13,700	219	12.01	83.8	3.41
March	1,980	23	5.6	197	549	......	38,100	12,200	121	10.40	82.4	2.51
April	3,710	22	10.4	136	139	......	20,400	3,470	132	8.74	77.8	2.26
May	800	25	18.4	194	218	......	44,900	10,400	208	7.47	78.6	2.17
June	321	23	24.2	123	73	......	22,200	21,900	165	7.90	92.9	1.58
July	121	24	25.2	229	91	......	25,700	19,100	141	7.79	93.3	2.08
August	52	26	23.5	245	62	......	15,400	11,500	67	8.28	96.3	2.76

TABLE No. 48.—*Summary of bacteriological observations and dissolved oxygen determinations, by stations—Monthly means at each station with corresponding means of discharge and related data*—Continued

SAMPLING STATION 120—ILLINOIS RIVER 120.2 MILES ABOVE GRAFTON AND ABOVE TOWN OF HAVANA AND JUNCTION OF SPOON RIVER

Month	Average discharge (second-feet)	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	Bacteria per cubic centimeter: On gelatin at 20° C. 48 hours	Bacteria per cubic centimeter: On agar at 37° C. 24 hours	Bacteria per cubic centimeter: B. coli (estimated)	Dissolved oxygen: Initial: Parts per million	Dissolved oxygen: Initial: Per cent saturation	Dissolved oxygen: Loss on incubation for 5 days at 20° C. (parts per million)
1921												
July	10,800	28	29.4	141	106	......	64,100	47,900	345	2.02	31.9	4.20
August	10,100	26	23.5	137	132	......	80,300	70,800	721	3.06	42.9	4.45
September	12,100	24	24.0	135	142	......	98,800	69,300	808	4.04	47.8	4.85
October	13,800	25	12.6	146	62	......	28,400	25,100	344	7.35	68.6	4.34
November	16,300	23	6.1	152	68	......	17,800	10,700	116	9.35	74.5	4.00
December	26,300	24	2.8	162	37	......	13,200	3,210	[1] 98	11.03	81.3	5.25
1922												
January	22,300	23	.6	167	20	......	......	1,510	[2] 30	9.78	68.4	5.03
February	17,300	22	1.6	158	77	......	30,300	5,340	[2] 73	9.16	65.6	5.62
March	34,900	25	5.5	147	85	......	19,000	4,400	[1] 130	10.46	82.7	5.61
April	50,600	23	11.8	136	64	......	6,180	1,680	[1] 12	8.97	82.6	3.13
May	28,600	25	19.4	153	34	......	8,070	2,940	[1] 30	7.60	79.5	4.96
June	15,600	25	25.1	160	69	......	40,000	48,500	[3] 842	5.20	62.2	6.36
July	12,400	24	26.0	128	111	......	46,200	47,400	[3] 422	5.08	62.5	7.24
August	10,300	26	26.2	135	65	......	32,800	28,400	[3] 156	4.60	56.8	7.08

SAMPLING STATION SPOON—SPOON RIVER AT MOUTH

Month	Average discharge (second-feet)	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	Bacteria per cubic centimeter: On gelatin at 20° C. 48 hours	Bacteria per cubic centimeter: On agar at 37° C. 24 hours	Bacteria per cubic centimeter: B. coli (estimated)	Dissolved oxygen: Initial: Parts per million	Dissolved oxygen: Initial: Per cent saturation	Dissolved oxygen: Loss on incubation for 5 days at 20° C. (parts per million)
1921												
July	195	25	28.0	131	617	......	31,900	15,200	44	4.70	59.4	2.15
August	397	25	23.6	116	898	......	41,900	32,000	101	5.52	64.3	2.35
September	735	24	23.3	123	1,080	......	80,200	52,000	197	5.71	66.2	2.01
October	332	24	12.6	184	420	......	28,800	24,000	212	7.35	69.1	2.29
November	206	22	6.0	230	244	......	33,800	15,400	72	10.56	84.9	3.02
December	888	24	2.3	208	208	......	51,400	24,200	98	11.88	86.9	4.28
1922												
January	765	22	.3	171	114	......	60,000	4,620	34	10.32	71.2	4.73
February	1,310	22	1.7	159	200	......	80,800	11,300	109	9.26	66.6	5.65
March	1,640	24	5.4	158	120	......	120,000	24,000	171	10.33	81.9	4.80
April	2,800	4	12.0	66	1,040	......	61,100	35,500	280	8.56	85.4	2.22
May	1,780	17	21.1	174	1,130	......	37,900	20,100	174	6.28	70.6	2.76
June	497	24	25.1	201	173	......	15,800	8,400	84	6.67	79.8	3.21
July	1,030	24	25.6	176	910	......	43,700	22,800	151	6.70	80.8	5.38
August	103	26	25.9	192	77	......	4,150	6,350	62	5.70	69.2	5.16

SAMPLING STATION 101—ILLINOIS RIVER 101.8 MILES ABOVE GRAFTON AND ABOVE MOUTH OF SANGAMON RIVER

Month	Average discharge (second-feet)	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	Bacteria per cubic centimeter: On gelatin at 20° C. 48 hours	Bacteria per cubic centimeter: On agar at 37° C. 24 hours	Bacteria per cubic centimeter: B. coli (estimated)	Dissolved oxygen: Initial: Parts per million	Dissolved oxygen: Initial: Per cent saturation	Dissolved oxygen: Loss on incubation for 5 days at 20° C. (parts per million)
1921												
July	10,700	12	28.2	144	161	......	33,400	64,800	56	2.98	37.4	2.68
August	10,300	10	25.2	133	198	......	25,800	31,800	74	3.07	36.8	4.31
September	12,600	12	24.3	136	160	......	22,300	36,000	252	3.76	44.2	6.98
October	13,800	12	14.7	151	110	......	13,200	8,200	121	8.07	78.9	6.15
November	16,600	8	11.4	155	88	......	6,860	5,260	111	10.08	91.8	5.92

[1] Samples taken at station 120.9.
[2] Samples taken at station 119.9 because of ice in river.
[3] Samples taken at stations 120.9 and 119.9.

TABLE No. 46.—*Summary of bacteriological observations and dissolved oxygen determinations, by stations—Monthly means at each station with corresponding means of discharge and related data*—Continued

SAMPLING STATION SANGAMON—SANGAMON RIVER AT MOUTH

Month	Average discharge (second-feet)	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	Bacteria per cubic centimeter			Dissolved oxygen		
							On gelatin at 20° C. 48 hours	On agar at 37° C. 24 hours	B. coli (estimated)	Initial		Loss on incubation for 5 days at 20° C. (parts per million)
										Parts per million	Per cent saturation	
1921												
July	743	12	28.2	160	132	......	19,100	32,600	123	4.23	53.6	2.48
August	1,130	12	25.6	136	179	......	18,100	15,700	190	3.23	38.5	3.71
September	1,970	11	24.5	141	147	......	16,500	16,400	148	4.39	52.0	6.45
October	1,310	13	14.6	160	112	......	7,480	6,220	105	9.41	91.8	5.66
November	3,380	5	11.4	165	78	......	4,070	3,280	26	11.48	104.6	5.98

SAMPLING STATION 88—ILLINOIS RIVER 88.8 MILES ABOVE GRAFTON, AT TOWN OF BEARDSTOWN

1921												
July	11,800	22	28.6	147	129	......	24,000	31,300	24	2.65	33.8	2.81
August	11,700	27	25.2	134	219	......	26,800	29,100	136	2.97	35.6	4.25
September	15,000	25	24.6	128	201	......	24,700	25,900	220	3.74	43.9	6.30
October	15,100	26	14.6	152	129	......	16,100	9,700	72	8.29	80.9	4.65
November	17,800	11	11.4	155	93	......	7,650	4,870	[1] 127	9.85	89.7	5.15

SAMPLING STATION 84—ILLINOIS RIVER 84 MILES ABOVE GRAFTON AND IMMEDIATELY ABOVE MOUTH OF CROOKED CREEK

1921												
July	11,600	10	28.6	151	86.5	......	20,200	22,600	5	2.94	37.6	2.04

SAMPLING STATION 78—ILLINOIS RIVER 78 MILES ABOVE GRAFTON AND IMMEDIATELY ABOVE LAGRANGE DAM

1921												
July	12,100	8	28.0	148	104	......	26,400	20,300	31	3.02	38.1	2.65

SAMPLING STATION CROOKED CREEK—CROOKED CREEK AT MOUTH

1921												
July	192	10	28.6	166	117	......	5,280	10,100	2	5.56	71.0	1.52
August	565	14	24.8	95	887	......	10,400	12,800	48	4.70	55.9	2.48
September	1,800	12	22.8	100	1,090	......	41,200	80,000	542	5.47	62.8	4.24
October	319	12	14.7	128	545	......	62,100	17,100	289	8.12	79.0	4.02
November	313	5	11.6	156	222	......	7,080	2,670	6	10.04	91.9	4.16

SAMPLING STATION 77.—ILLINOIS RIVER, 76.7 MILES ABOVE GRAFTON AND 1 MILE BELOW LAGRANGE DAM

1921												
July	12,100	9	28.2	144	101	......	18,100	22,600	58	3.60	45.6	2.13
August	12,000	14	25.1	133	194	......	16,000	16,800	116	3.19	38.2	3.56
September	15,600	12	23.6	139	232	......	23,400	21,100	187	4.42	51.6	5.90
October	15,500	11	14.8	156	133	......	12,000	8,160	47	8.07	79.0	5.06
November	18,100	5	11.6	152	112	......	5,880	4,030	[1] 26	9.50	87.7	5.14

---

[1] Laboratory discontinued, effective Nov. 15, 1921.

TABLE No. 46.—*Summary of bacteriological observations and dissolved oxygen determinations, by stations—Monthly means at each station with corresponding means of discharge and related data*—Continued

SAMPLING STATION 43.—ILLINOIS RIVER, 42.9 MILES ABOVE GRAFTON

Month	Average discharge (second-feet)	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	Bacteria per cubic centimeter			Dissolved oxygen		
							On gelatin at 20° C. 48 hours	On agar at 37° C. 24 hours	B. coli (estimated)	Initial		Loss on incubation for 5 days at 20° C. (parts per million)
										Parts per million	Per cent saturation	
1921												
July	12,300	12	26.8	146	168	......	9,500	11,400	35	4.30	54.9	2.42
August	12,300	14	25.4	134	344	......	27,700	10,000	178	2.18	37.9	2.93
September	16,000	12	22.7	137	574	......	25,300	15,000	314	2.61	41.6	4.30
October	15,800	12	14.1	165	210	......	19,200	4,900	46	7.75	74.7	3.80
November	16,300	12	7.8	166	156	......	16,100	4,400	62	9.78	81.4	4.30
December	22,700	10	4.2	165	110	......	7,300	1,370	18	11.03	84.9	3.00
1922												
February	21,900	8	1.7	162	311	......	37,500	2,940	22	10.71	76.9	3.36
March	36,700	13	5.8	137	320	......	25,100	3,690	16	10.48	83.6	2.74
April	89,400	3	9.6	143	155	......	......	......	......	9.61	82.9	2.30
May	51,800	11	20.2	159	87	......	7,000	10,400	36	7.09	77.7	4.16
June	25,000	12	25.6	169	142	......	11,500	15,300	27	4.30	52.6	2.68
July	16,100	12	26.2	145	280	......	11,300	5,800	35	3.27	39.9	3.13
August	12,100	12	26.4	141	100	......	2,570	2,260	7	3.86	47.2	2.91

SAMPLING STATION 32.—ILLINOIS RIVER, 31.5 MILES ABOVE GRAFTON AND IMMEDIATELY ABOVE KAMPSVILLE DAM

Month	Average discharge (second-feet)	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	On gelatin at 20° C. 48 hours	On agar at 37° C. 24 hours	B. coli (estimated)	Parts per million	Per cent saturation	Loss on incubation for 5 days at 20° C. (parts per million)
1921												
July	12,400	25	28.9	146	165	......	4,600	3,300	21	4.99	65.2	2.63
August	12,400	12	25.7	128	400	......	22,600	8,500	212	3.14	38.0	1.91

SAMPLING STATION 31.—ILLINOIS RIVER, 30.9 MILES ABOVE GRAFTON AND 0.6 MILE BELOW KAMPSVILLE DAM

Month	Average discharge (second-feet)	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	On gelatin at 20° C. 48 hours	On agar at 37° C. 24 hours	B. coli (estimated)	Parts per million	Per cent saturation	Loss on incubation for 5 days at 20° C. (parts per million)
1921												
July	12,400	35	26.0	141	172	......	5,620	5,470	22	5.30	66.5	2.79
August	12,400	27	24.7	134	328	......	12,800	7,270	149	4.19	49.5	2.53
September	16,200	24	21.3	134	530	......	20,000	10,600	111	3.95	45.6	3.08
October	15,900	25	14.5	151	192	......	11,900	3,900	26	7.91	77.6	3.67
November	18,400	24	7.8	156	169	......	17,100	4,000	30	9.97	82.7	4.66
December	34,100	25	3.8	169	115	......	10,600	1,350	24	11.06	84.6	3.56
1922												
January	29,300	25	.6	172	269	......	26,100	2,890	12	11.14	77.5	3.90
February	22,100	23	1.8	159	454	......	34,400	2,410	15	11.06	78.9	5.06
March	37,200	26	5.9	138	587	......	22,600	3,300	21	10.45	88.4	2.85
April	91,200	7	9.4	135	173	......	10,500	2,810	34	9.34	81.3	1.81
May	53,000	22	20.2	157	87	......	4,780	5,500	19	7.12	78.1	4.27
June	26,400	20	25.9	166	156	......	5,100	6,430	22	4.25	53.6	4.39
July	16,300	25	26.2	146	302	......	9,600	4,650	18	3.66	44.9	3.21
August	12,200	27	26.6	143	99	......	2,450	1,500	9	4.55	56.6	3.33

TABLE No. 46.—*Summary of bacteriological observations and dissolved oxygen determinations, by stations—Monthly means at each station with corresponding means of discharge and related data*—Continued

SAMPLING STATION [illegible]—ILLINOIS RIVER [illegible] MILES ABOVE GRAFTON AND ABOVE JUNCTION OF MACOUPIN CREEK

Month	Average discharge (second-feet)	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	Bacteria per cubic centimeter			Dissolved oxygen		
							On gelatin at 20° C. 48 hours	On agar at 37° C. 24 hours	B. coli (estimated)	Initial		Loss on incubation 5 days at 20° C. (parts per million)
										Parts per million	Per cent saturation	
1921												
July	13,400	13	28.2	147	157	......	9,590	9,900	19	3.04	40.2	2.69
August	12,400	12	23.7	139	408	......	16,000	8,290	190	4.08	48.1	2.84
September	16,200	12	23.6	134	475	......	10,600	10,400	137	3.82	44.8	2.16
October	15,900	12	14.5	148	211	......	7,600	3,600	38	7.73	75.8	2.28
November	18,400	11	7.4	160	176	......	17,300	3,570	67	9.73	80.7	4.80
December	34,100	11	4.5	172	139	......	6,000	1,660	14	11.61	84.4	3.90
1922												
February	25,100	6	1.9	153	700	......	46,000	5,430	14	11.18	80.5	3.80
March	27,200	12	6.3	139	413	......	15,600	2,910	16	10.17	82.1	2.66
April	91,200	4	9.0	140	399	......	11,300	7,710	250	9.23	80.7	1.98
May	53,600	10	20.1	134	98	......	5,370	6,080	15	7.01	78.6	4.80
June	26,400	12	25.9	160	149	......	7,910	8,700	380	4.26	51.5	4.36
July	16,300	12	26.2	145	250	......	5,430	5,440	380	3.53	43.1	2.75
August	17,200	13	25.0	144	98	......	2,580	2,000	5	4.32	52.6	3.47

SAMPLING STATION MACOUPIN—MACOUPIN CREEK AT MOUTH

1921												
July	59	13	27.5	149	340	......	14,900	18,400	274	3.61	45.2	2.16
August	236	12	24.9	105	534	......	25,800	14,200	189	4.34	54.0	2.92
September	221	12	22.7	107	578	......	28,900	15,200	207	5.16	60.2	2.56
October	55	13	13.4	129	316	......	17,100	11,200	134	6.86	64.7	2.40
November	767	11	7.5	171	287	......	42,300	7,490	140	7.90	65.6	3.59
December	890	10	5.6	173	130	......	36,300	3,210	34	11.03	87.6	3.20
1922												
February	409	4	3.1	206	161	......	7,040	1,300	5	11.71	87.1	3.46
March	3,170	10	7.0	120	717	......	23,400	6,810	25	10.20	85.1	2.92
April	5,600	4	12.0	96	1,040	......	61,100	35,800	2000	8.06	81.8	2.29
May	244	10	20.0	173	124	......	9,300	11,300	30	5.59	61.6	7.21
June	91	13	25.3	196	57	......	6,980	17,800	22	6.30	73.6	4.73
July	26	12	25.6	224	138	......	5,140	6,190	11	5.75	69.4	3.99
August	19	13	25.1	209	80	......	3,060	3,460	10	5.26	63.2	4.57

SAMPLING STATION MISSISSIPPI—MISSISSIPPI RIVER AT HAMBURG, ILL., 40 MILES ABOVE GRAFTON AND JUNCTION WITH THE ILLINOIS RIVER

1921												
August	......	5	25.0	144	95	......	26,900	12,400	16	7.26	86.5	2.26
September	......	9	24.0	150	577	......	13,800	5,030	128	6.50	77.3	2.45
October	......	9	15.1	161	120	......	6,040	2,840	30	9.16	90.6	2.29
November	......	9	7.9	150	100	......	6,480	1,540	41	11.56	97.1	3.34
December	......	9	2.7	164	89	......	7,780	1,280	94	12.74	93.7	3.97
1922												
January	......	8	.3	167	219	......	16,400	2,480	22	13.21	91.8	4.09
February	......	9	1.1	172	191	......	11,300	1,470	5	12.60	89.2	4.53
March	......	9	5.3	91	852	......	69,300	4,670	17	11.09	87.2	4.90
April	......	9	10.0	106	350	......	7,600	1,700	22	10.56	95.9	2.02
May	......	9	20.2	100	188	......	7,750	2,440	13	7.58	83.6	2.24
June	......	9	25.3	129	181	......	2,900	2,380	19	6.62	80.2	2.35
July	......	8	25.5	115	350	......	7,200	3,700	22	6.54	78.9	2.25
August	......	9	25.8	184	154	......	3,830	2,770	27	7.00	85.8	2.77

TABLE No. 47.—*Summary of bacteriological observations and dissolved oxygen determinations, by months—Monthly means at all stations, with corresponding means of discharge and related data*

JULY, [illegible]

Sampling station	Average discharge (second-feet)	Time of flow in hours from station [illegible]	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	Bacteria per cubic centimeter			Dissolved oxygen		
								On gelatin at 20° C. 48 hours	On agar at 37° C. 24 hours	B. coli (estimated)	Initial		Loss on incubation for 5 days at 20° C. (parts per million)
											Parts per million	Per cent saturation	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fox	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Vermilion	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mackinaw	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Spoon	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sangamon	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Crooked Creek	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Macoupin	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE No. 47.—*Summary of bacteriological observations and dissolved oxygen determinations, by months—Monthly means at all stations, with corresponding means of discharge and related data*—Continued

AUGUST, 192[illegible]

Sampling station	Average discharge (second-feet)	Time of flow in hours from station 292	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	Bacteria per cubic centimeter			Dissolved oxygen		
								On gelatin at 20° C. 48 hours	On agar at 37° C. 24 hours	B. coli (estimated)	Initial		Loss on incubation for 5 days at 20° C. (parts per million)
											Parts per million	Per cent saturation	
Summit	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Des Plaines	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
290.7-288.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
287.9-287.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Kankakee	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fox	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Vermilion	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
179	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mackinaw	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Spoon	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sangamon	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Crooked Creek	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
77	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mississippi	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

SEPTEMBER, 1921

Summit	8,200		25	19.2	186			2,870,000	1,910,000	[illegible]	1.45	18.9	[illegible]
291	8,200	0	24	20.1	[illegible]	23	18.2	2,430,000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Des Plaines	66		24	19.8	173	4		214,000	267,000	[illegible]	[illegible]	[illegible]	4.01
[illegible]			24	20.4	[illegible]	22		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]			24	20.4	[illegible]	22		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	4,080	1.3	24	20.4	[illegible]	22		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	5,080	2.0	23	20.1	[illegible]	[illegible]	34.0	[illegible]	[illegible]	[illegible]	[illegible]	11.7	[illegible]
Kankakee	1,280		22	22.3	[illegible]	[illegible]		6,200	4,000	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	9,930	14.4	24	21.0	[illegible]	[illegible]	28.3		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	10,080	32.5	20	22.7	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	1.79	[illegible]	[illegible]
Fox	567		20	21.7	[illegible]	[illegible]		17,400	17,000	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	10,900	41.6	22	20.8	157	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Vermilion	[illegible]		22	21.8	[illegible]	136		[illegible]	24,700	[illegible]	[illegible]	[illegible]	[illegible]
198	11,500	88.9	24	21.6	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
179	11,700	136	24	21.4	[illegible]	[illegible]	28.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
166	11,800	157	20	22.0	[illegible]	87	58.0	3,110	2,000	[illegible]	[illegible]	[illegible]	[illegible]
163	11,900	210	24	22.5	[illegible]	76		47,000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
149	11,900	215	24	22.9	[illegible]	111		[illegible]	214,000	[illegible]	[illegible]	[illegible]	[illegible]
Mackinaw	830		24	21.0	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
136	12,100	227	24	24.0	[illegible]	143		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Spoon	738		24	23.3	[illegible]	1,080		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	12,600	257	13	24.3	[illegible]	180		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sangamon	1,970		11	24.8	141	147		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	14,000	[illegible]	20	24.0	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Crooked Creek	[illegible]		12	22.8	[illegible]	1,080		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
77	[illegible]	[illegible]	12	22.6	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
43	16,000	[illegible]	12	22.7	177	374		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21	16,200	[illegible]	24	22.3	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	16,200	[illegible]	12	22.5	[illegible]	473		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Macoupin	231		12	22.7	157	379		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mississippi			6	24.0	[illegible]	577		[illegible]	6,000	[illegible]	[illegible]	[illegible]	[illegible]

TABLE No. 47.—*Summary of bacteriological observations and dissolved oxygen determinations, by months—Monthly means at all stations, with corresponding means of discharge and related data*—Continued

OCTOBER, 1921

Sampling station	Average discharge (second-feet)	Time of flow in hours from station 292	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	Bacteria per cubic centimeter: On gelatin at 20° C. 48 hours	Bacteria per cubic centimeter: On agar at 37° C. 24 hours	Bacteria per cubic centimeter: B. coli (estimated)	Dissolved oxygen: Initial: Parts per million	Dissolved oxygen: Initial: Per cent saturation	Dissolved oxygen: Loss on incubation for 5 days at 20° C. (parts per million)
Summit	[illegible]		31	12.4	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
292	[illegible]	0	25	12.8	[illegible]	[illegible]	22.8	[illegible]	2,370,000	[illegible]	[illegible]	[illegible]	[illegible]
Des Plaines	[illegible]		26	12.9	[illegible]	[illegible]		[illegible]	2,110	21	[illegible]	[illegible]	[illegible]
288.7–288.1			26	12.7	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
287.9–287.3			26	11.9	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	1.3	26	12.8	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	2.0	26	12.7	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	3.5	5		[illegible]	[illegible]	26.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Kankakee	[illegible]		24	12.2	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	14.0	[illegible]	13.3	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	22	[illegible]	14.0	[illegible]	[illegible]	46.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fox	[illegible]		17	12.8	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	41.4	[illegible]	12.4	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Vermilion	[illegible]		[illegible]	15.0	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	67.2	[illegible]	12.0	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	13.2	[illegible]	[illegible]	23.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	13.3	[illegible]	[illegible]	24.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	14.8	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	215	[illegible]	16.0	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mackinaw	[illegible]		[illegible]	12.3	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	12.6	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Spoon	[illegible]		[illegible]	12.6	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	14.7	[illegible]	130		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sangamon	[illegible]		[illegible]	14.6	[illegible]	113		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	14.6	[illegible]	120		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Crooked Creek	[illegible]		19	14.7	[illegible]	140		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	11	14.8	[illegible]	130		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	12	14.1	[illegible]	210		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	14.8	[illegible]	182		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	13	14.5	[illegible]	211		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Missouri	[illegible]		[illegible]	12.4	[illegible]	316		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mississippi			8	13.1	[illegible]	120		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

NOVEMBER, 1921

Summit	8,870	----------	24	8.0	129	----------	----------	1,020,000	225,000	11,200	7.50	63.2	12.50
292	8,870	0	23	7.9	121	48	39.1	857,000	467,000	10,400	4.37	36.3	12.28
Des Plaines	896	----------	22	4.5	175	32	----------	11,700	12,200	324	10.05	77.4	3.08
288.7-288.1	----------	----------	24	6.8	140	43	----------	402,000	264,000	4,600	6.36	52.0	11.57
287.9-287.3	----------	----------	23	7.2	125	47	----------	621,000	371,000	13,900	5.11	42.2	12.10
283	9,750	1.3	24	7.0	133	45	----------	512,000	318,000	9,250	5.74	47.2	11.84
280	9,750	2.0	25	6.9	127	48	52.8	525,000	292,000	9,450	6.51	53.3	13.18
278	9,790	5.5	12	7.2	127	43	----------	458,000	185,000	[illegible]	6.49	53.5	10.88
Kankakee	4,240	----------	23	7.3	169	65	----------	5,300	5,190	0	11.05	98.5	2.73
263	15,300	14.1	23	7.6	131	53	62.6	489,000	251,000	6,820	5.42	45.2	11.90
240	15,500	29.0	17	6.1	137	65	----------	245,000	71,400	1,920	6.83	54.8	6.03
Fox	2,170	----------	17	4.7	224	23	----------	6,910	2,450	121	11.32	93.9	2.83
227	17,800	38.1	19	6.4	146	62	----------	202,000	88,000	1,810	6.34	51.3	6.7
Vermilion	1,020	----------	19	7.1	208	84	----------	24,000	8,650	194	10.39	85.6	2.40
196	17,900	85.2	23	7.3	155	77	----------	49,500	12,200	276	8.51	70.5	4.68
179	16,600	141	22	7.5	153	63	46.2	31,400	5,830	294	7.15	59.7	3.73
166	16,100	187	24	8.0	149	40	23.7	13,900	2,330	60	9.22	77.8	3.25
152	16,100	208	23	7.6	150	47	----------	22,300	24,100	138	9.42	78.6	4.00
148	16,200	213	23	7.4	150	55	----------	23,900	18,600	105	9.27	76.9	4.62
Mackinaw	522	----------	25	7.2	138	132	----------	27,100	10,600	34	10.55	87.1	2.76
122	16,300	232	23	6.1	153	65	----------	17,800	10,700	118	9.23	74.5	4.68
Spoon	399	----------	22	6.0	220	244	----------	23,800	15,400	73	10.50	84.9	3.02
101	16,600	252	5	11.4	155	86	----------	6,860	5,260	111	10.08	91.8	5.22
Sangamon	3,590	----------	5	11.4	162	78	----------	4,070	3,200	26	11.45	104.6	5.86
89[1]	17,800	262	11	11.4	155	93	----------	7,050	4,870	127	9.85	89.7	5.15
Crooked Creek	313	----------	5	11.6	156	222	----------	7,090	2,670	6	10.04	91.9	4.16
77[1]	18,100	272	5	11.6	152	112	----------	5,800	4,030	38	9.59	87.7	5.14
43	18,300	282	12	7.5	[illegible]	186	----------	16,100	4,420	42	9.75	81.4	4.20
31	18,400	291	24	7.8	156	169	----------	17,100	4,000	39	9.57	82.7	4.03
20	18,400	296	11	7.4	156	176	----------	17,200	3,570	57	9.72	80.7	4.30
Macoupin	767	----------	11	7.6	171	267	----------	42,300	7,490	140	7.86	66.6	3.30
Mississippi	----------	----------	9	7.8	156	100	----------	6,460	1,540	41	11.75	97.1	3.24

---

[1] Laboratory discontinued, effective Nov. 15, 1921.

TABLE No. 47.—*Summary of bacteriological observations and dissolved oxygen determinations, by months—Monthly means at all stations, with corresponding means of discharge and related data*—Continued

DECEMBER, 1921

Sampling station	Average discharge (second-feet)	Time of flow in hours from station 292	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	Bacteria per cubic centimeter			Dissolved oxygen		
								On gelatin at 20° C. 48 hours	On agar at 37° C. 24 hours	B. coli (estimated)	Initial		Loss on incubation for 5 days at 20° C. (parts per million)
											Parts per million	Per cent saturation	
Summit	8,070		23	4.2	130			498,000	81,900	3,220	10.45	78.8	13.93
292	8,670	0	25	3.2	118	73	61.8	654,000	290,000	9,210	7.64	57.0	16.39
Des Plaines	1,610		24	1.3	161	71		31,300	17,000	255	11.38	80.5	3.37
288.7–288.1			25	3.4	122	80		613,000	253,000	7,890	7.81	58.6	16.45
287.9–287.3			25	3.1	128	81		631,000	276,000	7,050	8.21	61.1	14.73
[illegible]	10,400	1.3	26	3.3	128	81		682,000	304,000	7,790	8.31	63.0	14.67
[illegible]	10,400	2.0	24	3.1	137	75	65.2	500,000	219,000	7,110	9.29	69.5	13.98
278	10,500	5.4	11	4.0	137	79		541,000	129,000	3,370	8.45	64.6	10.44
Kankakee	5,800		25	4.0	188	21		3,120	3,880	131	11.85	89.9	2.30
[illegible]	17,900	13.5	24	3.7	159	77	61.3	394,000	203,000	3,710	8.39	63.4	10.93
240	18,100	26.6	22	2.0	160	72		251,000	27,000	1,980	8.75	71.5	8.98
Fox	3,580		21	1.9	212	64		17,800	6,000	315	12.96	88.5	3.13
[illegible]	21,900	35.3	19	2.3	188	82		329,000	36,900	1,610	9.75	71.0	6.93
Vermilion	1,270		19	1.3	200	91		29,100	6,310	110	13.08	89.7	2.63
196	24,000	62.5	25	2.9	162	22		36,[illegible]	3,030	138	11.85	91.5	4.20
179	24,600	140	24	2.9	159	23	27.1	27,200	3,130	97	10.10	75.9	4.21
166	24,900	177	22	2.9	159	27	21.9	28,[illegible]	1,680	55	11.98	88.1	2.51
[illegible]	25,100	195	25	4.2	159	41		19,700	4,820	33	11.90	88.2	3.32
[illegible]	25,200	199	24	3.8	159	31		19,700	4,770	68	10.95	82.1	2.73
Mackinaw	1,140		23	4.2	221	147		29,100	4,980	130	11.38	88.3	3.33
123 [1]	26,300	215	24	2.8	182	37		19,200	3,210	68	11.78	91.5	5.33
Spoon	808		24	2.3	220	[illegible]		51,600	24,300	50	11.90	88.0	4.38
43	33,700	267	10	4.2	188	110		7,280	1,270	15	11.03	85.3	2.23
21	34,100	275	25	3.8	189	115		10,600	1,220	94	11.68	88.0	2.93
[illegible]	34,100	279	11	4.3	173	120		9,080	1,540	14	11.01	86.4	3.33
Macoupin	830		10	5.6	173	153		46,300	3,210	54	11.05	87.6	3.13
Mississippi			9	2.7	164	86		7,780	1,380	56	12.74	88.7	3.67

JANUARY, 1922

Summit	8,310	----	29	1.2	130	----	----	181,000	58,500	2,820	11.15	75.8	17.75
292	8,310	0	24	.3	121	42	30.6	619,000	55,400	3,980	9.75	67.2	20.72
Des Plaines	498	----	24	.0	213	19	----	22,700	12,800	187	8.68	69.0	4.89
[illegible].7–[illegible].1	----	----	24	.5	126	45	----	661,000	126,000	2,380	9.57	67.0	20.59
287.9–287.3	----	----	24	.3	128	46	----	594,000	106,000	3,120	10.12	69.8	19.75
[illegible]	8,700	1.3	24	.6	129	48	----	688,000	115,000	2,880	9.86	68.5	20.23
[illegible]	8,700	2.0	24	.5	125	42	36.9	640,000	92,000	3,430	11.61	77.0	18.67
273	8,720	5.5	12	1.6	127	40	----	508,000	70,800	3,100	10.42	74.5	15.28
Kankakee	4,980	----	24	1.1	184	34	----	19,400	7,770	30	12.96	81.1	2.45
263	14,000	14.2	24	1.1	135	57	45.5	701,000	97,100	2,710	9.82	65.6	17.69
[illegible]	14,100	29.1	17	.5	136	73	----	375,000	33,800	1,880	10.41	72.2	16.70
Fox	2,380	----	17	.5	224	40	----	25,100	4,720	188	12.26	85.2	2.85
237	16,900	40.9	20	.4	156	42	----	275,000	34,300	1,020	10.15	72.3	6.40
Vermillion	448	----	18	.5	232	96	----	37,800	6,270	224	12.75	89.4	2.69
196	18,300	56.0	15	.9	160	14	----	56,300	4,500	225	8.84	63.0	6.83
179	19,800	148	23	.1	161	17	19.3	68,800	3,700	209	8.16	56.0	2.39
166	20,100	189	20	.2	163	26	21.9	42,300	1,450	140	8.53	58.7	3.56
158	20,500	208	24	.6	164	37	----	45,000	8,250	144	5.94	62.2	3.15
148	20,600	212	13	1.0	161	52	----	----	3,800	243	9.05	67.7	3.26
Mackinaw	625	----	8	1.7	216	745	----	37,100	10,100	190	11.84	82.7	2.57
122 [1]	22,300	230	22	.8	167	39	----	----	1,510	39	9.73	68.4	5.05
Spoon	765	----	22	.3	171	114	----	69,000	4,630	34	10.22	71.2	4.73
81	29,300	292	23	.6	172	259	----	30,100	2,350	13	11.14	77.5	2.90
Mississippi	----	----	8	.3	167	210	----	16,400	2,490	22	13.31	91.8	4.06

---

[1] Samples taken at station 120.9.

[2] Samples taken at station 119.9 because of ice in river.

TABLE No. 47.—*Summary of bacteriological observations and dissolved oxygen determinations, by months—Monthly means at all stations, with corresponding means of discharge and related data*—Continued

FEBRUARY, 1922

Sampling station	Average discharge (second-feet)	Time of flow in hours from station 293	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	Bacteria per cubic centimeter			Dissolved oxygen		
								On gelatin at 20° C. 48 hours	On agar at 37° C. 24 hours	B. coli (estimated)	Initial		Loss on incubation for 5 days at 20° C. (parts per million)
											Parts per million	Per cent saturation	
Summit	8,380		28	2.0	129			198,000	46,100	1,580	11.70	84.5	19.84
293	8,390	0	21	1.0	130	35	34.3	667,000	81,900	5,200	9.11	64.0	22.49
Des Plaines	121		18	.2	224	33		71,700	23,600	21	6.18	42.5	4.22
288.7–288.1			21	.6	122	38		717,000	128,000	3,130	9.03	62.7	24.88
287.9–287.3			21	1.1	122	37		812,000	100,000	6,280	9.22	65.0	26.88
286	8,330	1.3	21	.9	123	34		794,000	112,000	2,600	9.12	64.0	24.45
281	8,390	2.0	21	1.6	123	35	32.8	882,000	117,000	2,160	10.13	73.0	23.68
278	8,380	5.5	9	2.4	124	45		971,000	74,800	3,900	8.34	60.9	22.73
Kankakee	3,870		21	1.0	100	76		46,200	9,970	128	11.30	82.8	3.69
263	12,300	14.5	21	1.8	132	50	46.8	800,000	100,000	3,190	7.73	54.5	28.88
260	12,500	31.3	21	.0	142	36		381,000	25,700	1,810	8.13	56.5	10.88
Fox	1,160		22	.0	262	15		21,000	2,760	19	11.51	78.7	3.40
237	14,620	43.8	18	.9	146	82		301,000	34,800	2,700	9.26	64.5	[illegible]
Vermilion	706		10	.9	168	315		128,000	19,500	396	11.72	83.2	[illegible]
196	15,200	88.4	22	1.2	152	31		158,000	7,840	335	8.05	61.1	[illegible]
179	13,800	145	22	.5	153	29	22.8	102,000	3,160	395	7.70	54.0	[illegible]
166	15,900	190	23	.9	154	21	19.3	30,800	847	89	7.77	54.5	[illegible]
160	16,100	211	22	.4	155	24		41,400	22,100	224	8.48	[illegible]	[illegible]
148	16,100	216	18	.5	154	37		38,200	18,200	225	8.30	[illegible]	[illegible]
Mackinaw	618		11	.7	213	228		101,000	12,700	219	12.01	[illegible]	[illegible]
133[1]	17,300	255	25	1.8	186	77		30,300	3,340	73	9.15	[illegible]	[illegible]
Spoon	1,310		22	1.3	159	200		89,800	11,800	108	9.06	[illegible]	[illegible]
43	21,900	294	8	1.7	162	311		37,500	2,840	27	10.71	75.8	[illegible]
31	22,100	302	22	1.6	159	454		34,400	2,410	13	11.06	78.8	[illegible]
26	22,100	307	8	1.9	152	789		46,000	5,430	14	11.16	80.5	[illegible]
Macoupin	400		4	2.1	266	181		7,940	1,360	6	11.71	87.1	[illegible]
Mississippi			9	1.1	172	161		11,800	1,470	5	12.68	88.8	[illegible]

MARCH, [illegible]

Summit	5,740	----------	31	4.0	120	----------	----------	267,000	33,200	2,880	10.80	88.7	28.00
290	5,740	0	26	2.7	122	48	27.4	297,000	68,600	4,060	7.86	88.5	19.00
Des Plaines	1,080	----------	26	3.1	118	149	----------	157,000	55,000	173	9.52	73.1	4.[illegible]
[illegible]	----------	----------	27	(4.0)	120	[illegible]	----------	405,000	94,700	[illegible]	7.73	[illegible]	[illegible]
[illegible]	----------	----------	26	4.0	122	[illegible]	----------	612,000	95,000	[illegible]	7.82	[illegible]	[illegible]
[illegible]	[illegible]	1.5	26	4.0	122	[illegible]	----------	512,000	96,400	[illegible]	7.77	[illegible]	[illegible]
[illegible]	[illegible]	2.0	26	4.6	120	[illegible]	34.7	[illegible]	150,000	[illegible]	8.95	[illegible]	18.07
273	[illegible]	5.4	13	4.4	124	[illegible]	----------	555,000	95,200	1,450	7.77	[illegible]	17.[illegible]
Kankakee	[illegible]	----------	25	5.0	146	[illegible]	----------	22,400	7,430	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	18,[illegible]	18.5	24	4.7	[illegible]	134	98.5	[illegible]	110,000	[illegible]	7.39	67.2	[illegible]
260	[illegible],100	25.9	[illegible]	2.9	141	118	----------	206,000	[illegible]	1,310	9.06	67.5	[illegible]
Fox	[illegible]	----------	[illegible]	3.4	165	[illegible]	----------	106,000	10,[illegible]	120	11.06	87.1	[illegible]
227	[illegible],100	[illegible].1	[illegible]	4.8	141	[illegible]	----------	442,000	[illegible]	[illegible]	8.94	[illegible]	[illegible]
Vermilion	[illegible]	----------	[illegible]	4.7	177	[illegible]	----------	37,200	11,[illegible]	[illegible]	11.36	87.3	2.17
196	[illegible],100	[illegible].0	[illegible]	4.8	144	97	----------	95,200	7,750	[illegible]	9.46	73.0	7.[illegible]
179	[illegible],700	[illegible]	[illegible]	4.4	162	79	29.3	68,500	4,450	136	9.11	76.0	[illegible]
166	[illegible],100	176	27	5.5	144	[illegible]	27.8	[illegible]	1,760	[illegible]	10.36	81.1	[illegible]
158	[illegible],400	197	[illegible]	4.9	143	73	----------	[illegible],000	16,200	[illegible]	10.31	[illegible]	[illegible]
148	[illegible],500	201	[illegible]	4.9	146	70	----------	30,100	11,300	[illegible]	10.39	[illegible]	4.[illegible]
Mackinaw	1,[illegible]	----------	[illegible]	5.6	157	[illegible]	----------	[illegible],100	12,[illegible]	[illegible]	10.48	[illegible]	2.11
120 ¹	[illegible]	219	[illegible]	5.5	147	85	----------	19,000	4,400	[illegible]	10.46	[illegible]	[illegible]
Spoon	1,[illegible]	----------	[illegible]	5.4	[illegible]	130	----------	128,000	24,000	171	10.38	91.9	4.[illegible]
43	[illegible],700	271	13	5.8	137	[illegible]	----------	[illegible],100	3,030	[illegible]	10.42	[illegible].0	[illegible].70
31	37,[illegible]	276	[illegible]	5.9	139	[illegible]	----------	[illegible]	3,200	[illegible]	10.46	[illegible].4	[illegible]
[illegible]	37,[illegible]	[illegible]	13	6.8	139	413	----------	18,[illegible]	2,910	14	10.17	[illegible].1	[illegible]
Macoupin	[illegible],370	----------	10	7.0	[illegible]	717	----------	[illegible],400	6,510	[illegible]	10.[illegible]	[illegible].1	[illegible]
Mississippi	----------	----------	8	[illegible]	91	[illegible]	----------	[illegible]	4,670	17	11.[illegible]	87.2	4.[illegible]

¹ Samples taken at stations 120.9 and 119.9.

² Samples taken at station 120.9.

TABLE NO. 47.—*Summary of bacteriological observations and dissolved oxygen determinations, by months—Monthly means at all stations, with corresponding means of discharge and related data*—Continued

APRIL, 1923

Sampling station	Average discharge (second-feet)	Time of flow in hours from station 292	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	Bacteria per cubic centimeter: On gelatin at 20° C. 48 hours	Bacteria per cubic centimeter: On agar at 37° C. 24 hours	Bacteria per cubic centimeter: B. coli (estimated)	Dissolved oxygen: Initial: Parts per million	Dissolved oxygen: Initial: Per cent saturation	Dissolved oxygen: Loss on incubation for 5 days at 20° C. (parts per million)
Summit	8,480	----------	29	8.3	131	----------	----------	312,000	62,800	3,800	7.86	68.7	12.96
292	8,480	0	24	8.6	115	47	28.1	1,300,000	186,000	16,400	[illegible]	[illegible]	6.78
Des Plaines	1,000	----------	23	9.0	163	87	----------	22,900	4,980	95	[illegible]	77.0	[illegible]
288.7-288.1	----------	----------	23	(8.9)	124	83	----------	1,140,000	185,000	8,120	[illegible]	[illegible]	[illegible]
287.9-287.3	----------	----------	24	8.9	127	74	----------	1,270,000	221,000	9,080	[illegible]	[illegible]	[illegible]
[illegible]	10,200	1.3	24	8.9	128	78	----------	1,280,000	198,000	8,880	[illegible]	41.5	[illegible]
[illegible]	10,300	2.0	24	9.4	130	75	65.9	1,190,000	190,000	8,880	[illegible]	[illegible]	[illegible]
[illegible]	10,400	5.4	9	[1] (9.4)	124	68	----------	1,190,000	182,000	3,880	[illegible]	[illegible]	[illegible]
Kankakee	18,600	----------	24	10.7	105	340	----------	21,800	6,000	62	[illegible]	[illegible]	[illegible]
[illegible]	28,300	12.7	24	10.8	110	373	104.0	309,000	37,900	1,980	[illegible]	[illegible]	[illegible]
[illegible]	34,000	22.9	23	9.2	126	316	----------	154,000	31,300	1,220	[illegible]	[illegible]	[illegible]
Fox	4,880	----------	14	9.0	202	80	----------	14,800	3,380	207	[illegible]	[illegible]	[illegible]
227	39,000	29.4	22	10.1	130	187	----------	67,100	14,800	788	[illegible]	[illegible]	[illegible]
Vermilion	4,880	----------	23	10.2	160	256	----------	25,800	7,080	178	[illegible]	[illegible]	[illegible]
[illegible]	45,700	60.8	24	10.4	138	166	----------	16,700	2,100	71	[illegible]	[illegible]	[illegible]
[illegible]	46,700	102	23	10.3	132	100	60.8	12,900	1,610	87	[illegible]	[illegible]	[illegible]
[illegible]	47,300	123	23	11.2	132	71	35.9	6,380	1,880	13	[illegible]	[illegible]	[illegible]
[illegible]	47,800	149	22	9.6	124	73	----------	20,800	2,380	97	[illegible]	[illegible]	[illegible]
[illegible]	45,800	152	23	9.6	132	84	----------	12,700	2,070	110	[illegible]	77.3	[illegible]
Mackinaw	3,710	----------	22	10.4	126	130	----------	30,400	3,470	182	[illegible]	77.8	[illegible]
[illegible] [2]	30,600	166	21	11.8	126	66	----------	6,150	1,080	12	[illegible]	[illegible]	[illegible]
Spoon	2,880	----------	4	12.0	66	1,040	----------	61,100	35,800	280	[illegible]	[illegible]	[illegible]
[illegible]	88,400	204	3	9.0	146	168	----------	----------	----------	----------	[illegible]	[illegible]	[illegible]
[illegible]	91,200	209	7	9.4	126	173	----------	10,800	2,810	84	[illegible]	[illegible]	[illegible]
[illegible]	91,300	211	4	9.0	142	228	----------	11,[illegible]	7,710	30	[illegible]	[illegible]	[illegible]
Macoupin	5,600	----------	4	12.0	66	1,040	----------	61,100	36,800	280	[illegible]	[illegible]	[illegible]
Mississippi	----------	----------	2	10.0	168	366	----------	7,600	1,750	28	10.[illegible]	[illegible]	[illegible]

MAY, 1923

Summit	2,910		31	14.5	128			1,600,000	167,000	12,300	3.20	52.6	16.37
[illegible]	2,910	0	25	14.0	130	24	26.8	2,342,000	300,000	45,000	.41	4.0	12.49
Des Plaines	261		25	15.2	228	40		3,210	1,310	16	2.80	86.0	5.66
[illegible].7–[illegible].1			25	(15.4)	131	28		1,600,000	315,000	19,300			
[illegible].9–[illegible].3			25	15.4	134	20		1,600,000	341,000	25,300			
[illegible]	3,030	1.3	25	15.4	135	29		1,600,000	300,000	22,300			
[illegible]	3,010	2.0	25	15.0	134	21	46.1	1,360,000	200,000	14,100	2.09	26.5	14.37
[illegible]	3,070	5.5	14	³ (15.0)	138	25		1,160,000	185,000	11,300	1.13	11.0	14.77
Kankakee	5,180		25	16.7	171	80		8,400	2,780	17	7.06	52.2	1.45
[illegible]	14,200	13.9	25	16.8	161	47	69.3	317,000	94,900	6,100	1.91	19.8	9.46
247	15,600		17	16.7	160	46		65,800	25,900	857	1.97	20.1	5.28
[illegible]	16,400	28.0	25	⁴ (17.0)	165	42		79,000	28,500	1,070	3.42	34.0	6.32
Fox	1,480		25	18.0	218	19		6,600	2,380	62	7.96	77.3	1.67
[illegible]	17,650	37.1	25	17.2	168	46		55,800	10,400	540	3.39	33.9	7.30
Vermilion	775		25	19.3	190	45		5,600	1,820	87	6.13	87.5	1.94
[illegible]	20,300	84.6	22	18.6	155	35		18,300	6,130	30	3.11	60.7	4.35
179	22,600	142	20	18.4	165	42	44.5	3,710	1,390	16	4.69	51.7	3.90
[illegible]	23,600	180	25	19.2	153	33	22.1	1,790	707	12	7.04	75.6	3.72
[illegible]	24,400	198	25	18.6	164	56		22,600	37,500	370	7.19	76.8	4.19
[illegible]	24,600	202	25	18.5	162	88		57,100	39,100	220	7.05	74.7	4.44
Mackinaw	860		25	18.4	184	216		44,900	10,400	235	7.47	73.0	2.17
120 ²	26,000	216	25	19.4	188	34		5,070	2,040	90	7.40	73.8	4.64
Spoon	1,220		17	21.1	174	1,130		37,900	28,100	174	6.35	73.0	2.78
43	51,800	265	11	20.2	159	57		7,000	10,400	84	7.09	77.7	4.16
31	53,000	274	22	20.2	167	87		4,790	4,580	10	7.13	78.1	4.37
[illegible]	58,000	278	10	20.1	154	98		3,070	6,080	15	7.01	76.6	4.35
Macoupin	344		10	20.6	175	124		9,200	11,300	25	5.89	61.8	7.21
Mississippi			8	20.3	102	180		7,700	2,440	13	7.58	63.9	3.24

¹ Assumed same as for station [illegible].

² Samples taken at station 120.9.

³ Assumed same as for station 285.8.

⁴ Average temperature at 247.3 and 236.8.

TABLE No. 47.—*Summary of bacteriological observations and dissolved oxygen determinations, by months—Monthly means at all stations, with corresponding means of discharge and related data*—Continued

JUNE, 1922

Sampling station	Average discharge (second-feet)	Time of flow in hours from station 292	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	Bacteria per cubic centimeter			Dissolved oxygen		
								On gelatin at 20° C. 48 hours	On agar at 37° C. 24 hours	B. coli (estimated)	Initial		Loss on incubation for 5 days at 20° C. (parts per million)
											Parts per million	Per cent saturation	
Summit	9,370		30	19.7	120			1,620,000	718,000	26,300	2.44	26.4	16.05
292	9,370	0	26	20.9	136	29	33.9	2,500,000	1,830,000	56,000	.02	.3	14.60
Des Plaines	66		24	22.1	206	28		2,920	2,200	17	5.90	67.0	6.24
288.7-288.1			16	21.5	133	35		2,290,000	1,300,000	26,300			
287.9-287.3			14	20.2	136	30		2,410,000	1,490,000	31,500			
286	9,200	1.3	15	20.9	125	29		2,340,000	1,440,000	43,900			
280	9,200	2.0	21	20.5	120	30	66.8	1,370,000	984,000	28,100	1.22	20.0	13.84
273	9,280	5.5	12	¹20.5	136	27		1,060,000	738,000	15,700	.12	1.3	13.02
Kankakee	1,980		24	24.5	190	35		[illegible]	6,300	73	7.30	88.4	1.11
265	11,900	14.5	25	20.6	195	42	53.8	1,220,000	986,000	26,[illegible]	.30	3.0	12.02
247	11,900	26.7	27	21.0	136	36		260,000	226,000	7,300	.42	4.6	7.22
240	11,900	30.7	26	21.5	136	48		412,000	247,000	7,400	1.23	14.0	9.[illegible]
Fox	661		28	23.1	210	9		8,200	11,300	9	7.04	81.5	[illegible]
227	12,600	40.0	28	21.3	140	36		108,500	66,700	3,040	.[illegible]2	.6	8.10
Vermilion	108		28	24.9	198	64		14,400	5,900	84	6.20	74.1	1.[illegible]
198	14,600	67.6	25	23.5	148	43		37,300	22,700	686	2.08	31.3	6.[illegible]
179	15,900	144	23	23.6	147	23	30.1	3,020	3,000	73	2.33	28.6	2.[illegible]
166	16,600	180	20	24.3	145	34	29.9	3,550	1,900	96	5.20	60.4	5.[illegible]
152	16,900	210	22	24.6	146	53		66,100	130,000	1,640	6.03	71.3	6.0[illegible]
148	17,000	214	25	24.8	148	60		174,000	300,000	2,000	6.30	71.5	6.[illegible]
Mackinaw	321		28	24.3	123	73		22,200	21,900	166	7.90	92.9	1.[illegible]
128 ¹	18,600	229	25	25.1	150	62		46,900	46,500	640	5.20	62.3	6.[illegible]
Spoon	667		24	23.1	201	172		14,300	6,600	96	6.07	72.8	5.[illegible]
43	26,000	291	12	25.6	160	142		11,300	13,300	37	4.33	52.6	2.[illegible]
31	26,400	299	25	25.9	166	138		5,100	5,400	22	4.22	51.6	4.[illegible]
20	26,400	304	15	25.9	160	149		7,010	5,700	20	4.24	51.6	4.[illegible]
Macoupin	91		12	25.3	166	67		6,980	17,900	23	6.90	79.6	4.[illegible]
Mississippi			9	25.3	130	184		2,960	2,560	19	6.66	80.8	2.[illegible]

JULY, 1922

Summit	8,880	----	31	22.1	129	----	----	1,570,000	1,180,000	21,900	1.14	17.8	14.67
292	8,820	8	34	22.4	134	29	39.3	3,780,000	2,840,000	118,000	.01	.1	11.30
Des Plaines	40	----	34	22.9	212	59	----	7,550	10,300	14	6.30	73.6	7.24
285	8,780	2.0	36	22.6	135	27	46.9	1,780,000	1,810,000	19,400	1.46	18.7	7.10
273	8,780	5.5	19	22.9	136	28	----	1,610,000	1,780,000	21,800	.22	2.6	10.96
Kankakee	1,080	----	30	24.9	166	20	----	9,400	5,270	13	7.00	84.5	1.00
268	10,300	14.6	21	22.7	132	22	47.1	794,000	712,000	13,400	.15	1.7	6.02
267	10,400	27.2	22	23.1	133	29	----	983,000	873,000	10,900	.28	2.0	7.05
260	10,400	31.4	22	24.0	133	60	----	712,000	604,000	14,800	.09	3.7	6.92
Fox	211	----	22	24.7	180	13	----	9,360	6,080	31	7.05	65.7	1.16
227	10,923	46.7	24	22.9	184	45	----	153,000	142,000	2,940	.05	[illegible]	6.19
Vermilion	88	----	25	25.0	156	110	----	11,300	7,480	73	8.84	[illegible]	1.84
196	11,329	55.5	25	24.3	137	29	----	80,000	71,100	922	1.02	[illegible]	4.95
179	11,620	124	24	24.6	140	7	14.4	9,710	12,800	281	.79	[illegible]	3.08
166	11,580	155	25	24.8	157	38	37.7	7,910	2,380	29	5.06	67.4	5.28
152	11,780	209	25	25.5	137	61	----	29,925	60,000	261	6.17	76.7	6.00
145	11,780	214	24	25.5	129	107	----	268,000	262,000	2,040	7.16	[illegible]	7.87
Mackinaw	131	----	24	25.2	220	91	----	25,700	19,100	141	7.79	[illegible]	2.08
129[1]	12,650	257	26	26.0	128	111	----	44,200	47,400	442	5.00	[illegible]	7.38
Spoon	1,030	----	26	25.6	176	910	----	63,700	22,800	131	6.70	[illegible]	4.00
43	16,160	304	12	26.3	145	290	----	11,300	5,500	18	2.37	[illegible]	2.18
31	16,200	312	25	26.2	146	302	----	9,800	4,080	13	3.06	[illegible]	2.22
26	16,200	318	12	26.2	148	230	----	8,400	5,440	20	3.08	[illegible]	2.75
Macoupin	25	----	12	26.0	224	130	----	8,140	6,180	11	3.75	[illegible]	2.00
Mississippi	----	----	8	25.5	113	330	----	7,300	2,700	22	6.86	[illegible]	2.85

---

[1] Assumed same as for station 285.0.

[2] Samples taken at station 120.0.

TABLE No. 47.—*Summary of bacteriological observations and dissolved oxygen determinations, by months—Monthly means at all stations, with corresponding means of discharge and related data*—Continued

AUGUST, 1922

Sampling station	Average discharge (second-feet)	Time of flow in hours from station 293	Total days samples taken	Temperature of water (° C.)	Alkalinity (parts per million)	Turbidity (parts per million)	Suspended solids (parts per million)	Bacteria per cubic centimeter: On gelatin at 20° C. 48 hours	On agar at 37° C. 24 hours	B. coli (estimated)	Dissolved oxygen: Initial: Parts per million	Per cent saturation	Loss on incubation for 5 days at 20° C. (parts per million)
Summit	8,500		31	23.1	129			3,180,000	1,470,000	30,800	1.34	15.5	13.30
293	8,530	0	26	23.8	124	23	26.7	3,860,000	3,880,000	24,300	.01	1	11.88
Des Plaines	32		25	22.9	191	51		3,440	11,300	4	4.12	47.5	5.30
286	8,380	2.0	26	23.7	123	10	30.3	1,770,000	2,180,000	22,365	1.30	15.1	7.68
278	8,390	5.5	13	25.6	129	21		1,460,000	1,740,000	7,700	.30	3.8	7.94
Kankakee	713		26	24.5	164	19		9,300	7,370	3	6.50	75.9	.[illegible]
263	9,080	14.3	26	23.5	129	30	37.7	836,000	971,000	10,800	.16	1.9	7.32
247	9,670	27.0	25	23.3	129	21		1,040,000	1,040,000	10,400	.09	1.0	7.61
240	9,670	31.3	25	23.4	129	38		727,000	391,000	9,000	.22	2.7	8.08
Fox	337		25	23.4	223	3		168,000	38,000	4,870	6.11	75.9	1.62
227	10,000	40.0	23	23.7	131	31		200,000	94,700	3,370	.46	5.3	5.68
Vermilion	1		23	24.8	189	62		10,400	9,570	177	6.13	72.5	2.00
196	10,100	84.4	25	25.1	136	64		182,000	136,000	467	.08	11.3	7.99
179	10,100	150	27	24.5	137	16	13.9	80,000	55,700	166	.27	4.4	5.87
166	10,100	183	27	24.7	135	66	22.8	6,120	4,400	19	5.60	67.1	5.54
158	10,100	207	25	25.8	145	66		36,000	59,200	150	5.15	62.1	6.36
148	10,100	212	26	25.4	133	58		314,000	318,000	9,200	6.28	75.3	7.78
Mackinaw	53		26	23.8	265	68		16,400	11,500	67	5.30	65.3	7.08
122 [1]	10,250	239	26	26.2	135	53		22,800	26,600	129	4.65	58.8	7.08
Spoon	165		26	25.9	190	77		4,150	4,350	63	5.70	69.3	5.19
43	12,180	313	13	26.4	141	100		3,370	3,360	7	3.85	47.2	5.91
31	12,280	326	27	26.6	148	90		2,470	1,380	9	4.95	60.0	5.55
26	12,350	350	13	26.0	144	90		2,280	2,080	5	4.33	53.6	5.03
Macoupin	19		13	25.1	259	30		3,080	2,480	19	5.30	65.2	4.57
Mississippi			9	25.8	134	134		7,860	2,770	27	7.00	85.6	2.77

[1] Samples taken at station 120.9.

For purposes of comparative study of bacterial pollution of flowing streams it is essential that the actual quantities of bacteria be taken into account, as well as the concentration. Such quantities can be most conveniently expressed in terms of a unit in which is combined the elements of time, volume, and bacterial concentration. For this purpose a unit has been established which has been called the "quantity unit." The "quantity unit" may be defined as the product of 1 cubic foot discharge per second and a concentration of 1,000 bacteria per cubic centimeter. Hence the number of "quantity units" of bacteria in a stream is

$$\frac{\text{discharge in second-feet} \times \text{bacteria per c. c.}}{1{,}000}$$

Obviously this unit is convertible into bacterial numbers per unit of time such as the day. Thus an average of 1,000 bacteria per cubic centimeter in a flow of 1 second-foot for one day, or 86,400 seconds, is equivalent to

28,317[1] × 1,000 × 86,400 = 2,446,589,000,000 bacteria per day in one quantity unit

Bacterial concentration is apparently quite sensitive to changes in temperature, and it has been found advisable, therefore, to further arrange the data into definite groups in which the water temperatures are reasonably uniform. Such a presentation of results is given in Table No. 48. The bacteria growing on gelatin and on agar and the *B. coli* have been converted into quantity units, and the seasonal groupings of results arranged to include, for each sampling station, averages for such months where temperature changes are least variable. For this classification the months of June, July, August, and September are taken to be representative of summer conditions, during which time the water temperatures ranged from 20° to 30° C. For the winter period, data for the months of December, January, February, and March have been combined, the average water temperatures then being generally below 4° C. Between these two seasonal extremes the water is gradually adjusting itself to changing conditions of air temperatures, and it may be presumed the bacterial flora are likewise in a state of adjustment. To closely define the rate of such an accommodation of bacterial forms to temperature changes is not now essential, although it may be presumed that the transformation is gradual and may be roughly represented by average monthly results. Therefore, for purposes of comparative study, two further groupings of data are used, one embracing the results of May and October, termed the summer transitional season, when temperatures approach those of the summer season, and the other including the results of April and November, designated the winter transitional period, where the water temperatures deviate slightly from those prevailing in winter. A summation of these seasonal average data, arranged by sampling stations, for the gelatin, the agar, and the *B. coli* quantity units of bacteria is presented in Table No. 49.

---

[1] 28,317 cubic centimeters in 1 cubic foot.

TABLE No. 48.—*Summary of bacteriological observations by stations in terms of "quantity units" (bacteria per cubic centimeter × discharge in thousands of second-feet) monthly means and seasonal averages at each station*

SAMPLING STATION "SUMMIT"—CHICAGO DRAINAGE CANAL AT SUMMIT

Month	Discharge (thousand second-feet)	Bacteria per cubic centimeter			Quantity units—bacteria × thousand second-feet		
		Gelatin	Agar	B. coli	Gelatin	Agar	B. coli
1921—August	9.46	2,310,000	2,340,000	29,400	21,374,000	18,950,400	268,776
September	9.25	2,870,000	1,910,000	24,000	26,[illegible]	15,719,200	295,600
1922—June	9.37	1,830,000	719,000	26,300	17,147,100	6,737,000	246,421
July	9.85	1,670,000	1,180,000	21,800	16,540,000	10,443,000	192,900
August	8.33	2,160,000	1,470,000	20,900	18,460,300	12,324,400	174,040
Average	9.69	2,230,000	1,500,000	26,400	19,390,900	12,874,000	230,000
1921—December	8.67	493,000	81,900	3,220	4,274,310	710,073	27,917
1922—January	8.31	181,000	55,800	2,820	1,[illegible],110	464,[illegible]	23,434
February	8.39	196,000	46,100	1,560	1,642,400	386,215	13,072
March	8.74	267,000	36,200	2,600	2,333,580	301,948	22,600
Average	8.52	294,000	53,700	2,530	2,420,620	458,984	21,613
1921—October	8.84	1,330,000	794,000	31,300	11,765,200	6,789,780	267,362
1922—May	8.91	1,660,000	167,000	12,200	14,790,600	1,487,970	108,585
Average	8.72	1,530,000	480,000	21,900	13,287,900	4 134,200	138,448
1921—November	8.87	1,030,000	225,000	11,200	9,047,400	1,995,750	99,344
1922—April	8.48	812,000	92,900	2,900	6,885,700	702,144	32,234
Average	8.66	916,000	154,000	7,500	7,986,300	1,348,950	65,784

SAMPLING STATION NO. 280—CHICAGO DRAINAGE CANAL AT LOCKPORT

Month	Discharge (thousand second-feet)	Gelatin	Agar	B. coli	Gelatin	Agar	B. coli
1921—August	9.46	2,080,000	3,150,000	26,700	22,672,000	26,226,000	310,452
September	9.25	3,430,000	4,300,000	29,000	25,146,000	36,129,700	235,985
1922—June	9.37	2,860,000	1,960,000	56,800	26,794,500	16,660,000	532,216
July	8.85	2,790,000	3,540,000	118,000	22,450,000	32,384,000	1,044,300
August	8.83	2,560,000	3,900,000	24,300	22,376,000	33,904,900	295,940
Average	9.69	2,310,000	3,430,000	57,160	28,670,600	29,440,160	381,300
1921—December	8.67	664,000	230,000	9,210	5,486,790	1,994,100	79,880
1922—January	8.31	619,300	95,400	2,900	5,142,980	709,674	22,325
February	8.39	667,000	81,900	5,280	5,560,440	686,225	43,376
March	8.74	397,000	63,400	4,000	3,469,780	556,504	35,397
Average	8.53	578,000	115,000	5,390	4,919,980	986,460	47,784
1921—October	8.54	2,900,000	2,270,050	30,500	24,766,000	19,255,500	280,470
1922—May	8.91	3,240,000	591,000	40,300	28,868,400	5,265,910	369,946
Average	8.72	3,070,000	1,430,000	35,300	26,817,200	12,326,000	310,000
1921—November	8.87	857,000	467,000	10,400	7,601,590	4,142,290	92,248
1922—April	8.48	1,305,000	186,000	10,400	11,034,000	1,577,280	88,193
Average	8.66	1,080,000	326,000	10,400	9,312,900	2,859,780	90,220

TABLE NO. 48.—*Summary of bacteriological observations by stations in terms of "quantity units" (bacteria per cubic centimeter × discharge in thousands of second-feet) monthly means and seasonal averages at each station*—Continued

SAMPLING STATION NO. [illegible]—CHICAGO DRAINAGE CANAL AT LOCKPORT—CORRECTED FOR DIVERSION OF I. & M. CANAL AT JOLIET

Month	Discharge (thousand second-feet)	Bacteria per cubic centimeter			Quantity units—bacteria × thousand second-feet		
		Gelatin	Agar	B. coli	Gelatin	Agar	B. coli
1921—August	8.26	2,680,000	3,100,000	34,700	22,130,800	25,606,000	288,142
September	8.48	3,480,000	4,300,000	38,000	27,483,000	35,251,700	317,980
1922—June	9.17	2,840,000	1,800,000	56,800	26,134,800	16,506,000	520,800
July	8.65	3,780,000	3,840,000	118,000	32,697,000	33,216,000	1,020,700
August	8.32	3,800,000	3,600,000	34,500	31,616,000	28,196,800	287,040
Average	8.49	3,310,000	3,430,000	57,100	28,080,400	28,755,300	489,945
1921—December	8.47	624,000	230,000	9,210	5,280,097	1,948,100	78,000
1922—January	8.11	618,000	85,400	3,890	5,030,000	692,594	31,548
February	8.16	667,000	81,900	5,280	5,446,000	668,942	43,086
March	8.56	387,000	63,400	4,090	3,300,000	543,144	34,587
Average	8.33	579,000	115,000	5,590	4,898,130	963,446	46,670
1921—October	8.24	2,977,000	2,270,000	30,500	24,105,000	18,981,800	254,37
1922—May	8.71	3,240,000	591,000	40,500	28,230,400	5,147,610	352,756
Average	8.48	3,070,000	1,430,000	35,500	26,268,20	12,030,700	303,563
1921—November	8.67	857,000	467,000	10,400	7,430,190	4,048,890	90,168
1922—April	8.26	1,300,000	186,000	10,400	10,704,000	1,540,000	86,112
Average	8.46	1,080,000	326,000	10,400	9,067,100	2,794,400	88,140

SAMPLING STATION DES PLAINES—DES PLAINES RIVER AT LEMONT

Month	Discharge (thousand second-feet)	Gelatin	Agar	B. coli	Gelatin	Agar	B. coli
1921—August	0.011	138,000	151,000	1,600	1,518	1,661	18
September	.044	214,000	247,000	4,820	9,416	10,868	212
1922—June	.096	2,900	2,300	17	261	222	1
July	.040	7,550	10,300	14	302	412	1
August	.032	8,440	11,800	4	279	378	0
Average	.089	74,400	84,600	1,290	2,355	2,737	46
1921—December	1.61	31,300	17,000	265	50,793	27,370	427
1922—January	.469	32,700	12,900	187	15,121	6,308	92
February	.131	71,700	23,000	21	8,676	2,856	3
March	1.03	187,000	85,000	173	192,610	87,580	178
Average	.814	80,700	[illegible],000	163	66,950	31,064	175
1921—October	.196	5,680	3,110	21	1,125	616	4
1922—May	.251	5,210	1,310	16	1,308	329	4
Average	.224	5,440	2,210	18	1,216	472	4
1921—November	.895	11,700	12,200	324	10,463	10,951	290
1922—April	1.60	22,900	4,900	96	36,640	7,080	153
Average	1.248	17,300	8,550	210	23,552	9,449	221

TABLE No. 48.—*Summary of bacteriological observations by stations in terms of "quantity units" (bacteria per cubic centimeter × discharge in thousands of second-feet) monthly means and seasonal averages at each station*—Continued

SAMPLING STATION NO. [illegible]—DES PLAINES RIVER AT JOLIET—AVERAGE OF RESULTS OF STATIONS [illegible] AND [illegible]

Month	Discharge (thousand second-feet)	Bacteria per cubic centimeter			Quantity units = bacteria × thousand second-feet		
		Gelatin	Agar	B. coli	Gelatin	Agar	B. coli
1921—August	8.27	1,760,000	2,170,000	40,600	14,555,200	17,945,900	335,762
September	8.08	2,510,000	[illegible]	49,[illegible]	20,281,600	26,4[illegible]	[illegible]
1922—June	9.25	2,340,000	1,440,000	43,900	21,645,000	13,320,000	406,075
Average	8.53	2,200,000	2,170,000	44,700	15,855,000	18,282,000	380,500
1921—December	10.40	622,000	[illegible]	7,780	6,468,800	2,041,600	80,912
1922—January	8.70	638,000	115,000	2,860	5,550,600	1,000,500	24,882
February	8.33	704,000	112,000	3,690	5,864,320	932,960	30,738
March	9.78	513,000	89,400	3,330	5,017,140	874,332	32,670
Average	9.30	654,000	146,000	4,410	5,880,140	1,302,350	42,250
1921—October	8.78	1,880,000	1,470,000	32,200	16,504,200	12,906,600	282,716
1922—May	9.01	1,800,000	330,000	22,200	16,218,000	2,973,300	200,022
Average	8.90	1,840,000	900,000	27,200	16,361,100	7,939,950	241,369
1921—November	9.75	512,000	318,000	9,250	4,992,000	3,100,500	90,188
1922—April	10.20	1,297,000	188,000	8,860	[illegible]	1,917,600	90,372
Average	9.98	908,000	253,000	9,060	8,922,000	2,509,050	90,280

SAMPLING STATION NO. 286—DES PLAINES RIVER AT BRANDON BRIDGE

Month	Discharge (thousand second-feet)	Bacteria per cubic centimeter			Quantity units = bacteria × thousand second-feet		
		Gelatin	Agar	B. coli	Gelatin	Agar	B. coli
1921—August	8.27	954,000	1,470,000	24,700	7,889,580	12,156,900	204,269
September	8.08	2,030,000	2,370,000	31,500	16,402,400	19,149,600	254,520
1922—June	9.25	1,370,000	961,000	38,100	12,672,500	8,889,250	352,425
July	8.70	1,780,000	1,810,000	19,400	15,486,000	15,747,000	168,780
August	8.36	1,770,000	2,160,000	20,500	14,797,200	18,057,600	[illegible]
Average	8.53	1,580,000	1,750,000	27,200	13,467,700	14,800,100	238,619
1921—December	10.40	569,000	219,000	7,110	5,894,000	2,277,600	73,944
1922—January	8.70	640,000	98,000	3,430	5,568,000	852,600	29,841
February	8.33	882,000	117,000	2,100	7,347,060	974,610	17,493
March	9.78	534,000	130,000	2,630	5,222,520	1,271,400	25,721
Average	9.30	664,000	141,400	3,830	5,988,480	1,344,050	36,975
1921—October	8.78	1,580,000	1,220,000	48,200	13,872,400	10,711,600	423,196
1922—May	9.01	1,350,000	258,000	14,100	12,163,500	2,324,580	127,041
Average	8.90	1,465,000	739,000	31,150	13,018,000	6,518,090	275,118
1921—November	9.75	525,000	292,000	9,450	5,118,750	2,847,000	92,138
1922—April	10.20	1,180,000	189,000	8,800	12,036,000	1,927,800	89,760
Average	9.98	852,000	240,000	9,120	8,577,380	2,387,400	90,949

Table No. 48.—*Summary of bacteriological observations by stations in terms of "quantity units" (bacteria per cubic centimeter × discharge in thousands of second-feet) monthly means and seasonal averages at each station*—Continued

SAMPLING STATION NO. 278.—DES PLAINES RIVER AT CHANNAHON

Month	Discharge (thousand second-feet)	Bacteria per cubic centimeter			Quantity units = bacteria × thousand second-feet		
		Gelatin	Agar	B. coli	Gelatin	Agar	B. coli
1922—June	9.28	1,040,000	739,000	15,700	9,651,200	6,857,920	145,696
July	8.73	1,810,000	1,730,000	21,800	15,801,300	15,102,900	190,314
August	8.39	1,460,000	1,740,000	7,780	12,249,400	14,598,600	65,022
Average	8.80	1,440,000	1,400,000	15,100	12,567,300	12,186,500	133,677
1921—December	10.50	541,000	128,000	3,370	5,680,500	1,344,000	35,385
1922—January	8.72	506,000	70,000	3,100	4,412,320	610,400	27,032
February	8.33	971,000	74,800	3,800	8,088,430	623,084	31,654
March	9.82	505,000	95,200	1,450	4,959,100	934,864	14,239
Average	9.34	631,000	92,000	2,930	5,785,090	878,087	27,078
1921—October	8.81	643,000	509,000	----------	5,664,830	4,484,290	----------
1922—May	9.07	1,160,000	133,000	11,200	10,521,200	1,206,310	101,584
Average	8.94	901,000	321,000	11,200	8,093,010	2,845,300	101,584
1921—November	9.79	458,000	185,000	4,680	4,483,820	1,811,150	45,817
1922—April	10.40	1,190,000	133,000	3,900	12,376,000	1,383,200	40,560
Average	10.10	824,000	159,000	4,290	8,429,910	1,597,180	43,188

SAMPLING STATION KANKAKEE—KANKAKEE RIVER AT WILMINGTON

Month	Discharge (thousand second-feet)	Bacteria per cubic centimeter			Quantity units = bacteria × thousand second-feet		
		Gelatin	Agar	B. coli	Gelatin	Agar	B. coli
1921—August	0.708	1,660	1,650	8	1,175	1,168	6
September	1.23	5,290	4,520	32	6,507	5,560	39
1922—June	1.92	4,020	6,550	73	7,718	12,576	140
July	1.02	9,400	5,270	13	9,588	5,375	13
August	.713	9,500	7,270	3	6,773	5,184	2
Average	1.12	5,970	5,030	26	6,352	5,973	40
1921—December	5.80	8,120	3,880	131	47,096	22,504	760
1922—January	4.86	19,400	7,770	30	94,284	37,762	146
February	3.87	45,200	9,970	123	174,924	38,584	476
March	9.20	22,400	7,420	38	206,080	68,264	350
Average	5.93	23,800	7,260	80	130,596	41,778	433
1921—October	1.12	1,430	1,450	28	1,602	1,624	31
1922—May	5.16	8,400	2,780	17	43,344	14,345	88
Average	3.14	4,910	2,110	22	22,473	7,984	60
1921—November	4.84	5,300	5,190	40	25,652	25,120	194
1922—April	19.60	21,500	6,650	65	421,400	130,340	1,274
Average	12.22	13,400	5,920	52	223,526	77,730	734

TABLE No. 48.—*Summary of bacteriological observations by stations in terms of "quantity units" (bacteria per cubic centimeter × discharge in thousands of second-feet) monthly means and seasonal averages at each station*—Continued

SAMPLING STATION NO. [illegible]—ILLINOIS RIVER AT MORRIS

Month	Discharge (thousand second-feet)	Bacteria per cubic centimeter			Quantity units—bacteria × thousand second-feet		
		Gelatin	Agar	B. coli	Gelatin	Agar	B. coli
1921—August	9.12		530,000	8,530		4,826,770	77,796
September	9.92		2,270,000	31,600		22,518,400	313,472
1922—June	11.80	1,320,000	955,000	26,800	15,576,000	11,267,000	316,240
July	10.30	784,000	712,000	12,680	8,075,200	7,333,600	130,690
August	9.66	866,000	971,000	10,860	8,365,560	9,379,860	104,838
Average	10.16	987,000	1,090,000	18,090	10,640,000	11,065,100	188,570
1921—December	17.90	834,000	260,000	3,710	14,928,600	4,654,000	66,409
1922—January	14.00	701,000	97,100	2,710	9,814,000	1,359,400	37,940
February	12.20	560,000	100,000	2,190	6,840,000	1,220,000	26,257
March	19.90	665,000	110,000	2,500	13,233,500	2,189,000	49,750
Average	16.02	751,000	142,000	2,780	11,008,000	2,356,100	45,584
1921—October	10.50	414,000	336,000	11,800	4,347,000	3,528,000	123,900
1922—May	15.20	317,000	84,900	6,190	4,818,400	1,290,480	94,088
Average	12.85	365,000	210,000	9,000	4,582,700	2,409,240	108,994
1921—November	15.30	488,000	251,000	6,820	7,461,700	3,840,300	104,346
1922—April	33.20	309,000	37,900	1,640	10,258,800	1,258,280	54,448
Average	24.25	399,000	144,000	4,230	8,860,250	2,549,290	79,397

SAMPLING STATION NO. 247—ILLINOIS RIVER IMMEDIATELY ABOVE DAM AT MARSEILLES

Month	Discharge (thousand second-feet)	Bacteria per cubic centimeter			Quantity units—bacteria × thousand second-feet		
		Gelatin	Agar	B. coli	Gelatin	Agar	B. coli
1922—June	11.90	240,000	216,000	7,200	2,856,000	2,570,400	85,680
July	10.40	933,000	875,000	10,950	9,703,200	9,100,000	113,880
August	9.67	1,040,000	1,040,000	10,400	10,056,800	10,056,800	100,568
Average	10.66	738,000	710,000	9,500	7,538,670	7,242,400	99,980
1922—May	15.40	66,500	26,900	857	1,024,100	414,260	13,198

SAMPLING STATION NO. 240—ILLINOIS RIVER IMMEDIATELY ABOVE JUNCTION OF FOX RIVER AND ABOVE CITY OF OTTAWA

Month	Discharge (thousand second-feet)	Bacteria per cubic centimeter			Quantity units—bacteria × thousand second-feet		
		Gelatin	Agar	B. coli	Gelatin	Agar	B. coli
1921—July	9.22	728,000	643,000	13,600	6,712,160	5,926,040	125,392
August	9.20	422,000	493,000	3,770	3,882,400	4,535,600	34,684
September	10.00	290,000	332,000	3,970	2,900,000	3,320,000	39,700
1922—June	11.90	412,000	247,000	7,480	4,902,800	2,939,300	89,012
July	10.40	712,000	554,000	14,500	7,404,800	5,761,600	150,800
August	9.67	727,000	591,000	9,600	7,030,090	5,714,970	92,832
Average	10.06	548,000	470,000	8,820	5,472,040	4,699,580	88,737
1921—December	18.10	231,000	27,000	1,960	4,181,100	488,700	35,476
1922—January	14.10	375,000	33,200	1,850	5,287,500	468,120	26,085
February	12.50	381,000	25,700	1,810	4,762,500	321,250	22,625
March	20.10	305,000	28,500	1,310	6,130,500	572,850	26,331
Average	16.20	323,000	28,600	1,730	5,090,400	462,730	27,629
1921—October	10.60	214,000	140,000	3,950	2,268,400	1,484,000	41,870
1922—May	15.40	79,000	28,300	1,070	1,216,600	435,820	16,478
Average	13.00	146,000	84,200	2,510	1,742,500	959,910	29,174
1921—November	15.50	245,000	71,400	1,920	3,797,500	1,106,700	29,760
1922—April	34.00	184,000	31,200	1,220	6,256,000	1,060,800	41,480
Average	24.75	214,000	51,300	1,570	5,026,750	1,083,750	35,620

TABLE No. 48.—*Summary of bacteriological observations by stations in terms of "quantity units" (bacteria per cubic centimeter × discharge in thousands of second-feet) monthly means and seasonal averages at each station*—Continued

SAMPLING STATION FOX—FOX RIVER AT MOUTH

Month	Discharge (thousand second-feet)	Bacteria per cubic centimeter			Quantity units—bacteria × thousand second-feet		
		Gelatin	Agar	B. coli	Gelatin	Agar	B. coli
1921—July	0.225	13,400	8,940	124	3,015	2,011	28
August	.248	21,000	14,700	94	5,208	3,646	23
September	.807	17,400	17,600	27	14,042	14,203	22
1922—June	.621	8,200	11,300	9	5,092	7,017	6
July	.531	9,360	8,090	31	4,970	4,296	16
August	.327	100,000	58,000	4,870	32,700	18,966	1,592
Average	.460	28,200	19,800	859	10,838	8,356	281
1921—December	3.58	17,000	6,050	315	60,860	21,659	1,128
1922—January	2.26	35,100	4,730	168	79,326	10,690	380
February	1.15	31,000	2,780	19	35,650	3,197	22
March	3.24	106,000	10,800	120	343,440	34,992	389
Average	2.56	47,400	6,090	155	120,356	17,634	479
1921—October	1.66	11,800	6,620	25	19,588	10,989	41
1922—May	1.48	6,660	2,260	82	9,857	3,345	121
Average	1.57	9,230	4,440	54	14,722	7,167	81
1921—November	2.17	6,910	2,450	121	14,995	5,316	263
1922—April	4.56	15,800	3,360	267	72,048	15,322	1,218
Average	3.36	11,400	2,905	194	43,522	10,319	740

SAMPLING STATION NO. 227—ILLINOIS RIVER IMMEDIATELY ABOVE JUNCTION OF VERMILION RIVER AND ABOVE CITY OF LA SALLE

Month	Discharge (thousand second-feet)	Bacteria per cubic centimeter			Quantity units—bacteria × thousand second-feet		
		Gelatin	Agar	B. coli	Gelatin	Agar	B. coli
1921—July	9.50	157,000	119,000	5,790	1,491,500	1,130,500	55,005
August	9.48	66,500	72,500	1,190	630,420	687,300	11,281
September	10.90	67,300	73,800	1,470	733,570	804,420	16,023
1922—June	12.60	109,000	65,700	3,660	1,373,400	827,820	46,116
July	10.90	153,000	143,000	2,840	1,667,700	1,558,700	30,956
August	10.00	200,000	94,700	3,370	2,000,000	947,000	33,700
Average	10.56	125,000	94,800	3,050	1,316,100	992,623	32,180
1921—December	21.90	328,000	36,900	1,810	7,183,200	808,110	39,639
1922—January	16.90	275,000	24,200	1,090	4,647,500	408,980	18,421
February	14.60	361,000	24,800	2,700	5,270,600	362,080	39,420
March	26.10	443,000	38,500	2,940	11,562,300	1,004,850	76,734
Average	19.88	352,000	31,100	2,135	7,165,900	646,005	43,554
1921—October	12.30	106,000	68,300	1,330	1,303,800	840,090	16,359
1922—May	17.00	55,500	19,400	562	943,500	329,800	9,554
Average	14.65	80,700	43,800	946	1,123,650	584,945	12,956
1921—November	17.80	292,000	88,000	1,810	5,197,600	1,566,400	32,218
1922—April	39.00	87,100	14,800	788	3,396,900	577,200	30,732
Average	28.40	190,000	51,400	1,300	4,297,250	1,071,800	31,475

TABLE NO. 48.—*Summary of bacteriological observations by stations in terms of "quantity units" (bacteria per cubic centimeter × discharge in thousands of second-feet) monthly means and seasonal averages at each station*—Continued

SAMPLING STATION VERMILION—VERMILION RIVER AT MOUTH

Month	Discharge (thousand second-feet)	Bacteria per cubic centimeter			Quantity units = bacteria × thousand second-feet		
		Gelatin	Agar	B. coli	Gelatin	Agar	B. coli
1921—July	0.006	21,500	19,500	117	130	117	1
August	.002	10,200	14,000	37	20	28	0
September	.280	27,000	25,700	102	7,530	7,183	30
1922—June	.188	15,400	8,920	84	2,895	1,677	16
July	.088	11,300	7,430	73	994	654	6
August	.001	16,900	9,570	177	10	10	0
Average	.098	16,200	14,000	98	1,961	1,608	9
1921—December	1.27	33,100	6,810	110	42,037	8,649	140
1922—January	.443	37,800	6,270	204	16,745	2,778	90
February	.706	125,000	19,500	324	88,300	12,880	229
March	2.56	37,200	11,900	268	95,232	30,464	686
Average	1.245	58,300	11,100	212	60,578	13,694	286
1921—October	.187	9,450	8,030	289	1,767	1,502	54
1922—May	.775	5,560	1,820	37	4,309	1,410	29
Average	.481	7,500	4,930	163	3,038	1,456	42
1921—November	1.00	24,000	8,650	194	24,400	8,650	194
1922—April	4.57	25,500	7,080	178	116,616	32,356	813
Average	2.77	24,900	7,860	186	70,508	20,412	503

SAMPLING STATION NO. 195—ILLINOIS RIVER AT TOWN OF HENRY

Month	Discharge (thousand second-feet)	Bacteria per cubic centimeter			Quantity units = bacteria × thousand second-feet		
		Gelatin	Agar	B. coli	Gelatin	Agar	B. coli
1921—July	9.86	73,600	64,800	220	725,696	638,928	2,169
August	9.75	38,400	35,300	237	374,400	344,175	2,311
September	11.50	21,700	22,800	153	249,550	262,200	1,760
1922—June	14.40	27,500	22,700	378	396,000	326,880	5,434
July	11.30	59,900	71,100	302	676,870	803,430	3,413
August	10.10	192,000	126,000	467	1,939,200	1,272,600	4,717
Average	11.15	68,850	60,500	244	726,963	641,245	3,966
1921—December	24.60	35,100	3,560	135	863,460	87,576	3,672
1922—January	18.20	98,050	4,990	335	1,784,460	90,818	6,097
February	14.28	166,000	7,840	346	2,371,280	110,195	4,940
March	25.10	99,200	7,790	254	2,489,920	195,529	6,375
Average	20.62	98,460	6,070	269	1,880,230	123,279	5,121
1921—October	12.60	16,400	12,700	147	206,640	160,020	1,852
1922—May	20.20	16,200	6,120	30	327,640	123,624	606
Average	16.40	17,300	9,410	88	267,140	141,822	1,229
1921—November	17.90	49,500	12,200	276	886,050	218,380	4,940
1922—April	45.70	16,700	2,160	71	763,190	98,712	3,245
Average	31.80	33,100	7,180	174	824,620	158,546	4,093

TABLE No. 48.—*Summary of bacteriological observations by stations in terms of "quantity units" (bacteria per cubic centimeter × discharge in thousands of second-feet) monthly means and seasonal averages at each station*—Continued

SAMPLING STATION NO. 179—ILLINOIS RIVER AT TOWN OF CHILLICOTHE AND HEAD OF PEORIA LAKE

Month	Discharge (thousand second-feet)	Bacteria per cubic centimeter			Quantity units = bacteria × thousand second-feet		
		Gelatin	Agar	B. coli	Gelatin	Agar	B. coli
1921—July	10.00	68,200	44,100	1,420	682,000	441,000	14,200
August	9.80	18,400	20,200	61	180,320	197,960	598
September	11.70	13,900	13,100	131	162,630	153,270	1,533
1922—June	15.90	3,660	3,030	73	58,194	48,177	1,161
July	11.60	9,710	12,600	201	112,636	146,160	2,332
August	10.10	50,000	55,700	166	505,000	562,570	1,677
Average	11.50	28,300	24,960	347	271,980	208,128	3,627
1921—December	24.60	37,200	3,120	97	915,120	76,752	2,386
1922—January	19.80	92,800	3,700	289	1,839,100	73,320	5,630
February	15.60	102,000	3,140	368	1,591,200	48,984	5,741
March	22.70	69,500	4,660	136	1,576,950	105,782	3,223
Average	20.85	74,900	3,620	222	1,477,670	76,189	4,246
1921—October	12.80	9,760	4,800	84	124,928	61,280	1,075
1922—May	22.60	3,710	1,260	16	83,846	28,476	362
Average	17.70	6,730	3,005	50	104,387	44,878	718
1921—November	16.60	31,400	5,830	294	521,240	96,778	4,880
1922—April	46.70	12,800	1,610	37	597,760	75,187	1,728
Average	31.65	22,100	3,720	166	559,500	85,982	3,304

SAMPLING STATION NO. 166—ILLINOIS RIVER ABOVE CITY OF PEORIA AND AT OUTLET OF PEORIA LAKE

Month	Discharge (thousand second-feet)	Bacteria per cubic centimeter			Quantity units = bacteria × thousand second-feet		
		Gelatin	Agar	B. coli	Gelatin	Agar	B. coli
1921—July	10.10	5,350	3,420	5	54,035	34,542	51
August	9.96	2,470	1,100	11	24,601	10,956	110
September	11.80	3,310	2,830	13	39,058	33,394	153
1922—June	16.50	3,850	1,900	28	63,525	31,350	462
July	11.50	7,910	3,550	20	90,965	40,825	230
August	10.10	6,120	4,400	19	61,812	44,440	192
Average	11.66	4,830	2,870	16	55,666	32,584	200
1921—December	24.90	20,900	1,620	55	520,410	40,338	1,370
1922—January	20.10	42,300	1,450	140	850,230	29,145	2,814
February	15.80	30,800	847	59	486,640	13,383	932
March	23.10	28,900	1,760	26	667,590	40,656	601
Average	20.98	30,700	1,420	70	631,218	30,880	1,429
1921—October	12.80	1,920	962	18	24,576	12,314	230
1922—May	23.60	1,730	767	12	40,828	18,101	283
Average	18.20	1,820	864	15	32,702	15,208	256
1921—November	16.10	13,900	2,330	60	223,790	37,513	966
1922—April	47.20	6,830	1,080	12	322,376	50,976	566
Average	31.65	10,400	1,700	36	273,083	44,244	766

TABLE No. 48.—*Summary of bacteriological observations by stations in terms of "quantity units" (bacteria per cubic centimeter × discharge in thousands of second-feet) monthly means and seasonal averages at each station*—Continued

SAMPLING STATION NO. 138—ILLINOIS RIVER IMMEDIATELY ABOVE CITY OF PEKIN

Month	Discharge (thousand second-feet)	Bacteria per cubic centimeter			Quantity units = bacteria × thousand second-feet		
		Gelatin	Agar	B. coli	Gelatin	Agar	B. coli
1921—July	10.10	43,600	26,900	222	440,360	271,690	2,242
August	10.00	31,200	34,200	240	312,000	342,000	2,400
September	11.90	47,000	50,300	210	559,300	598,570	2,499
1922—June	10.90	98,100	120,000	1,480	1,117,000	2,180,160	27,985
July	11.70	29,800	66,000	261	348,660	772,200	3,054
August	10.10	35,000	50,300	130	353,500	570,030	1,313
Average	11.78	42,100	59,300	473	533,816	796,267	6,796
1921—December	25.10	19,700	4,820	38	494,470	120,982	954
1922—January	20.50	45,000	8,250	144	922,500	169,125	2,952
February	16.10	41,400	72,100	324	666,540	155,850	5,216
March	23.40	29,600	16,300	567	692,640	381,420	13,268
Average	21.28	33,900	12,900	268	694,036	206,894	5,586
1921—October	12.90	38,400	52,000	302	495,360	670,800	3,896
1922—May	24.40	32,800	37,500	370	800,320	915,000	9,028
Average	18.65	35,600	44,700	336	647,840	793,900	6,462
1921—November	16.10	22,300	24,100	138	359,030	388,010	2,222
1922—April	47.80	10,500	2,350	27	501,900	112,330	1,291
Average	31.95	16,400	13,220	83	430,465	250,170	1,756

SAMPLING STATION NO. 149—ILLINOIS RIVER IMMEDIATELY ABOVE JUNCTION OF MACKINAW RIVER

1921—July	10.20	369,000	245,000	4,380	3,763,800	2,499,000	44,676
August	10.00	359,000	305,000	1,870	3,590,000	3,050,000	18,700
September	11.90	235,000	214,000	2,070	2,796,500	2,546,600	24,633
1922—June	17.00	174,000	200,000	2,690	2,958,000	3,400,000	45,730
July	11.70	238,000	253,000	2,040	2,784,600	2,960,100	23,868
August	10.10	314,000	310,000	9,340	3,171,400	3,131,000	94,334
Average	11.82	281,000	254,000	3,730	3,177,280	2,931,120	41,990
1921—December	25.20	18,700	4,770	66	471,240	120,204	1,663
1922—January	20.60	....	3,500	242	....	72,100	4,985
February	16.10	38,200	18,200	223	615,020	293,020	3,590
March	23.50	30,100	11,300	191	707,350	265,550	4,488
Average	21.35	29,000	9,440	180	597,870	187,718	3,682
1921—October	12.90	32,300	42,300	582	416,670	545,670	7,508
1922—May	24.60	57,100	30,100	220	1,404,660	740,460	5,412
Average	18.75	44,700	36,200	401	910,665	643,065	6,460
1921—November	16.20	23,900	18,600	165	387,180	301,320	2,673
1922—April	48.00	12,700	2,670	110	609,600	128,160	5,280
Average	32.10	18,300	10,600	138	498,390	214,740	3,976

TABLE No. 48.—*Summary of bacteriological observations by stations in terms of "quantity units" (bacteria per cubic centimeter × discharge in thousands of second-feet) monthly means and seasonal averages at each station*—Continued

SAMPLING STATION MACKINAW—MACKINAW RIVER AT MOUTH

Month	Discharge (thousand second-feet)	Bacteria per cubic centimeter			Quantity units—bacteria × thousand second-feet		
		Gelatin	Agar	B. coli	Gelatin	Agar	B. coli
1921—July	0.104	34,600	33,300	25	3,598	3,463	3
August	.245	67,900	42,000	110	16,636	10,290	27
September	.842	48,300	34,400	446	40,669	28,965	375
1922—June	.263	28,300	26,960	165	7,447	7,090	58
July	.121	25,700	19,100	141	3,110	2,311	17
August	.052	15,400	11,500	67	801	598	3
Average	.271	36,700	26,700	161	11,845	8,668	80
1921—December	1.14	38,100	4,990	120	43,434	5,689	137
1922—January	.625	37,100	10,100	190	23,187	6,312	119
February	.618	133,000	13,700	219	82,418	8,467	135
March	1.90	38,100	12,200	121	72,390	23,180	230
Average	1.071	61,600	10,200	163	55,357	10,912	155
1921—October	.295	28,300	9,520	181	8,344	2,808	53
1922—May	.800	44,900	10,400	206	35,920	8,320	166
Average	.548	36,600	9,960	194	22,132	5,564	110
1921—November	.822	27,100	10,600	34	22,276	8,713	28
1922—April	3.71	20,400	3,470	132	75,684	12,874	490
Average	2.266	23,700	7,030	83	48,980	10,794	259

SAMPLING STATION NO. 122—ILLINOIS RIVER ABOVE TOWN OF HAVANA AND JUNCTION OF SPOON RIVER

Month	Discharge (thousand second-feet)	Bacteria per cubic centimeter			Quantity units—bacteria × thousand second-feet		
		Gelatin	Agar	B. coli	Gelatin	Agar	B. coli
1921—July	10.30	64,100	47,900	240	660,230	493,370	2,472
August	10.10	89,300	70,800	721	901,930	715,080	7,282
September	12.10	98,800	89,300	903	1,195,480	1,080,530	10,926
1922—June	18.60	49,000	48,500	842	911,400	902,100	15,661
July	12.40	46,200	47,400	452	572,880	587,760	5,605
August	10.20	33,800	28,400	159	344,760	289,680	1,622
Average	12.28	63,500	55,400	553	764,447	678,087	7,261
1921—December	26.30	13,200	2,210	88	347,160	58,123	2,314
1922—January	22.30	…………	1,510	39	…………	33,673	870
February	17.20	30,300	5,340	73	524,190	91,848	1,256
March	24.80	19,000	4,400	130	471,200	109,120	3,224
Average	22.65	20,800	3,410	83	447,517	73,191	1,916
1921—October	13.20	28,400	25,100	364	374,880	331,320	4,805
1922—May	28.00	8,070	3,640	30	225,960	101,920	840
Average	20.60	18,200	14,370	197	300,420	216,620	2,822
1921—November	16.30	17,800	10,700	118	290,140	174,410	1,923
1922—April	50.60	6,150	1,080	12	311,190	54,648	607
Average	33.45	12,000	5,890	65	300,665	114,529	1,265

TABLE No. 46.—*Summary of bacteriological observations by stations in terms of "quantity units" (bacteria per cubic centimeter × discharge in thousands of second-feet) monthly means and seasonal averages at each station*—Continued

SAMPLING STATION SPOON—SPOON RIVER AT MOUTH

Month	Discharge (thousand second-feet)	Bacteria per cubic centimeter			Quantity units=bacteria×thousand second-feet		
		Gelatin	Agar	B. coli	Gelatin	Agar	B. coli
1921—July	0.196	21,900	15,200	44	4,292	2,984	9
August	.397	41,900	32,000	101	16,634	12,704	40
September	.735	39,300	32,600	197	28,887	23,961	145
1922—June	.497	15,500	8,460	86	7,703	4,205	42
July	1.090	40,700	23,800	151	44,374	25,958	134
August	.105	4,160	4,260	63	437	448	6
Average	.601	31,200	22,950	107	18,742	13,705	66
1921—December	.808	51,400	24,200	80	41,531	19,554	65
1922—January	.765	69,000	4,420	26	52,785	3,381	20
February	1.310	89,800	11,300	100	117,638	14,803	131
March	1.640	120,000	24,000	171	196,800	39,360	280
Average	1.131	82,500	16,080	96	102,180	19,274	126
1921—October	.332	38,900	24,600	212	12,902	8,167	70
1922—May	1.320	37,900	20,100	174	50,028	26,533	230
Average	.826	38,300	22,300	193	31,455	17,350	150
1921—November	.399	33,600	15,400	72	13,404	6,145	29
1922—April	2.800	61,100	34,500	280	171,080	96,400	784
Average	1.60	47,400	26,400	176	92,262	52,772	406

SAMPLING STATION NO. 101—ILLINOIS RIVER ABOVE MOUTH OF SANGAMON RIVER

1921—July	10.70	33,400	54,500	56	357,380	583,150	599
August	10.20	25,500	22,000	74	260,590	224,540	763
September	12.60	23,300	26,000	252	293,580	327,600	3,175
Average	11.20	27,000	34,100	127	299,650	378,430	1,512
1921—October	13.80	12,200	8,230	121	168,360	113,574	1,670
November	16.60	6,800	5,280	111	112,876	87,648	1,843

SAMPLING STATION SANGAMON—SANGAMON RIVER AT MOUTH

1921—July	0.743	19,100	32,000	123	14,191	23,776	91
August	1.130	18,100	15,700	190	20,453	17,741	215
September	1.970	16,500	16,400	148	32,505	32,308	292
Average	1.281	17,900	21,400	154	22,383	24,608	199
1921—October	1.310	7,490	6,220	105	9,812	8,148	138
November	3.590	4,070	3,260	26	14,611	11,703	93

SAMPLING STATION NO. 89—ILLINOIS RIVER AT TOWN OF BEARDSTOWN

1921—July	11.80	24,000	31,300	24	283,200	369,340	283
August	11.70	26,800	29,100	186	313,560	340,470	1,391
September	15.00	24,700	25,800	220	370,500	387,000	3,300
Average	12.83	25,200	28,700	137	322,420	365,605	1,725
1921—October	15.10	16,100	9,700	72	243,110	146,470	1,087
November	17.80	7,650	4,870	127	136,170	86,686	2,261

SAMPLING STATION NO. 94—ILLINOIS RIVER IMMEDIATELY ABOVE MOUTH OF CROOKED CREEK

1921—July	11.80	20,200	22,600	5	238,360	266,680	59

TABLE No. 48.—*Summary of bacteriological observations by stations in terms of "quantity units" (bacteria per cubic centimeter × discharge in thousands of second-feet) monthly means and seasonal averages at each station*—Continued

SAMPLING STATION CROOKED CREEK—CROOKED CREEK AT MOUTH

Month	Discharge (thousand second-feet)	Bacteria per cubic centimeter			Quantity units—bacteria × thousand second-feet		
		Gelatin	Agar	B. coli	Gelatin	Agar	B. coli
1921—July	0.192	5,280	10,100	12	1,014	1,930	2
August	.365	16,460	12,900	46	5,876	7,232	26
September	1.580	41,200	50,000	540	61,800	75,000	813
Average	.712	19,000	24,300	200	22,897	26,057	280
1921—October	.319	63,100	17,100	290	20,120	5,455	92
November	.313	7,000	2,670	6	2,210	836	2

SAMPLING STATION No. 78—ILLINOIS RIVER IMMEDIATELY ABOVE LA GRANGE DAM

Month	Discharge (thousand second-feet)	Gelatin	Agar	B. coli	Gelatin	Agar	B. coli
1921—July	12.10	36,400	38,300	31	404,640	475,330	375

SAMPLING STATION NO. 77—ILLINOIS RIVER 1 MILE BELOW LA GRANGE DAM

Month	Discharge (thousand second-feet)	Gelatin	Agar	B. coli	Gelatin	Agar	B. coli
1921—July	12.10	16,100	22,000	56	210,010	266,200	677
August	12.60	15,000	15,500	116	190,000	196,000	1,390
September	15.60	23,400	21,100	187	365,040	329,160	2,917
Average	13.23	19,200	19,900	120	255,683	264,453	1,662
1921—October	15.50	13,000	8,180	47	201,500	126,400	728
November	15.10	5,800	4,830	26	105,630	72,943	393

SAMPLING STATION NO. 49—ILLINOIS RIVER 42.9 MILES ABOVE GRAFTON

Month	Discharge (thousand second-feet)	Gelatin	Agar	B. coli	Gelatin	Agar	B. coli
1921—July	12.20	9,500	11,400	29	115,900	140,220	344
August	12.30	27,700	10,000	175	340,710	123,000	2,152
September	14.00	28,300	15,000	314	406,800	210,000	5,024
1922—June	26.00	11,300	13,300	27	285,800	345,800	702
July	16.10	11,200	5,900	28	181,000	93,200	451
August	12.10	5,570	3,260	7	68,197	39,204	85
Average	15.60	14,600	9,860	96	230,214	165,201	1,460
1921—December	33.70	7,280	1,370	15	245,673	46,169	505
1922—February	21.90	37,800	2,940	23	821,280	62,196	462
March	36.70	23,100	3,630	16	847,770	133,221	587
Average	30.77	22,600	2,610	18	638,251	80,529	528
1921—October	15.90	19,200	4,960	44	305,260	75,654	695
1922—May	51.80	7,000	10,400	34	362,600	538,720	1,761
Average	33.80	13,100	7,680	39	333,930	306,700	1,228
1921—November	18.20	16,100	4,420	42	294,020	81,080	769
1922—April	88.40	....	....	....	....	....	....
Average	53.85	16,100	4,420	42	294,020	81,080	769

SAMPLING STATION NO. 23—ILLINOIS RIVER IMMEDIATELY ABOVE KAMPSVILLE DAM

Month	Discharge (thousand second-feet)	Gelatin	Agar	B. coli	Gelatin	Agar	B. coli
1921—July	12.40	4,660	5,300	21	57,784	65,720	260
August	12.40	23,900	8,500	212	296,360	105,400	2,630
Average	12.40	14,300	6,900	116	177,072	85,560	1,444

TABLE No. 48.—*Summary of bacteriological observations by stations in terms of "quantity units" (bacteria per cubic centimeter × discharge in thousands of second-feet) monthly means and seasonal averages at each station*—Continued

SAMPLING STATION NO. 31—ILLINOIS RIVER 0.6 MILE BELOW KAMPSVILLE DAM

Month	Discharge (thousand second-feet)	Bacteria per cubic centimeter			Quantity units=bacteria×thousand second-feet		
		Gelatin	Agar	B. coli	Gelatin	Agar	B. coli
1921—July	12.40	5,620	5,470	22	69,688	67,828	273
August	12.40	12,500	7,270	143	155,000	90,148	1,773
September	16.20	20,000	10,600	111	324,000	171,720	1,798
1922—June	26.40	5,100	5,430	22	134,640	143,352	581
July	16.30	9,600	4,650	18	156,480	75,795	293
August	12.20	2,400	1,590	9	29,280	19,398	110
Average	15.98	9,210	5,840	54	144,900	94,707	805
1921—December	34.10	10,600	1,320	24	361,460	45,025	818
1922—January	29.30	20,100	2,520	12	588,930	73,836	352
February	22.10	34,400	3,410	15	760,240	75,361	331
March	37.20	22,600	3,300	21	840,720	122,760	781
Average	30.68	21,900	2,640	18	637,838	79,468	570
1921—October	15.90	11,800	3,880	33	187,620	61,692	525
1922—May	53.00	4,780	5,560	19	253,340	294,680	1,007
Average	34.45	8,290	4,720	26	220,480	178,186	766
1921—November	18.40	17,100	4,000	39	314,640	73,600	718
1922—April	91.20	10,500	2,810	34	957,600	256,272	3,101
Average	54.80	13,800	3,410	36	636,120	164,936	1,909

SAMPLING STATION NO. 29—ILLINOIS RIVER ABOVE JUNCTION OF MACOUPIN CREEK

1921—July	12.40	9,350	9,900	13	115,940	122,760	161
August	12.40	18,000	9,240	136	223,200	114,576	1,686
September	16.20	19,000	10,400	137	307,800	168,480	2,219
1922—June	26.40	7,910	8,790	29	208,824	232,056	766
July	16.30	8,430	5,440	20	137,409	88,672	326
August	12.20	2,580	2,060	5	31,476	25,132	61
Average	15.98	10,900	7,640	57	170,775	125,279	870
1921—December	34.10	9,680	1,550	14	330,088	52,855	477
1922—February	22.10	46,000	5,420	14	1,016,600	119,782	309
March	37.20	18,000	2,910	14	669,600	108,252	521
Average	31.13	24,600	3,290	14	672,096	93,630	436
1921—October	15.90	7,950	3,690	26	126,451	58,671	413
1922—May	53.00	5,870	6,660	15	311,110	352,980	795
Average	34.45	6,910	5,180	20	218,780	205,826	604
1921—November	18.40	17,200	3,570	57	316,480	65,688	1,049
1922—April	91.20	11,300	7,710	39	1,030,560	703,152	3,557
Average	54.80	14,250	5,640	48	673,520	384,420	2,303

TABLE No. 48.—*Summary of bacteriological observations by stations in terms of "quantity units" (bacteria per cubic centimeter × discharge in thousands of second-feet) monthly means and seasonal averages at each station*—Continued

SAMPLING STATION MACOUPIN—MACOUPIN CREEK AT MOUTH

Month	Discharge (thousand second-feet)	Bacteria per cubic centimeter			Quantity units—bacteria × thousand second-feet		
		Gelatin	Agar	B. coli	Gelatin	Agar	B. coli
1921—July	0.080	14,900	16,400	273	1,336	1,536	26
August	.726	25,900	14,200	180	6,369	5,308	48
September	.201	28,940	14,200	300	6,085	2,743	70
1922—June	.091	6,900	17,900	22	626	1,630	2
July	.025	8,140	6,190	11	204	155	0
August	.010	5,000	2,440	10	50	68	0
Average	.114	16,860	12,700	134	2,966	1,726	25
1921—December	.880	56,300	3,210	54	49,730	2,984	45
1922—January							
February	.400	7,690	1,380	5	3,207	380	2
March	2.370	26,460	6,510	25	112,848	21,990	84
Average	1.525	22,500	3,700	28	54,166	8,391	44
1921—October	.085	17,100	11,200	124	1,453	952	11
1922—May	.344	9,200	11,300	25	3,165	3,887	9
Average	.214	13,200	11,300	69	2,309	2,420	10
1921—November	.797	42,300	7,490	140	33,444	5,743	107
1922—April	5.680	61,100	35,510	280	342,160	198,800	1,588
Average	3.184	51,700	21,500	210	187,802	102,272	848

TABLE No. 49.—*Summary of bacteriological observations at all sampling stations in terms of quantity units*

[Bacteria per cubic centimeter × discharge in thousands of second-feet. Means for gelatin count, agar count, and B. coli, respectively, for four seasonal periods]

1. GELATIN COUNTS

Sampling stations	Summer months		Winter months		Summer transitional (May and October)		Winter transitional (April and November)	
	Discharge	Bacteria	Discharge	Bacteria	Discharge	Bacteria	Discharge	Bacteria
	Second-feet	*Quantity units*	*Second-feet*	*Quantity units*	*Second-feet*	*Quantity units*	*Second-feet*	*Quantity units*
Summit	8.60	[1] 13,390,900	8.32	2,436,620	8.72	13,287,900	8.98	7,[illegible]
292	8.60	[1] 28,009,400	8.22	4,970,130	8.52	20,323,200	8.40	6,097,[illegible]
Des Plaines	.050	[1] 2,355	.814	68,900	.226	1,310	1.200	[illegible]
287	8.53	[1] 18,852,900	9.20	3,833,100	8.97	10,465,100	9.98	8,[illegible]
285	8.53	[1] 13,657,700	9.20	3,952,400	8.90	13,058,000	9.98	8,877,[illegible]
278	8.80	[2] 12,367,300	9.24	3,795,090	8.94	8,885,010	28.10	8,436,[illegible]
Kankakee	1.12	[1] 3,352	3.90	138,260	2.14	22,473	10.22	228,[illegible]
263	10.16	[2] 10,640,000	16.68	11,889,050	12.85	4,882,700	28.20	8,878,[illegible]
247	10.06	[2] 7,528,670			16.40	[4] 1,694,100		
240	10.06	5,472,040	16.20	5,080,400	13.06	1,742,800	28.75	5,086,700
Fox	.46	10,848	2.50	130,300	1.57	14,720	3.30	49,097
227	10.35	1,316,100	18.88	2,165,900	14.63	1,139,600	28.40	4,397,260
Vermilion	.098	1,981	1.265	49,628	.486	3,674	3.77	78,[illegible]
196	11.15	728,933	20.62	1,859,230	16.40	387,140	31.50	524,[illegible]
179	11.50	771,990	20.91	1,477,070	17.70	194,287	31.60	528,[illegible]
166	11.66	[illegible]	20.95	681,318	16.20	22,700	31.60	273,[illegible]
152	11.76	521,[illegible]	21.28	696,289	18.05	667,940	31.90	420,[illegible]
140	11.92	3,177,380	21.37	387,870	18.77	858,675	33.10	480,[illegible]
Mackinaw	.377	11,845	1.071	32,267	.348	21,262	2.200	43,[illegible]
122	12.26	704,447	22.08	667,317	20.00	300,430	38.45	380,[illegible]
Spoon	.494	18,743	1.131	169,188	.826	31,450	1.00	92,300
101	11.20	[6] 288,050			13.80	[6] 182,160	4.60	[7] 118,[illegible]
Sangamon	1.261	[6] 22,380			1.31	[6] 9,812	3.20	[7] 14,661
80	12.87	[6] 322,420			15.10	[6] 268,110	17.90	[7] 186,170
64	11.90	[6] 288,380						
Crooked Creek	.752	[6] 22,897			.310	[6] 20,130	.515	[7] 3,209
78	12.10	[6] 604,040						
77	13.23	[6] 258,605						
43	13.80	289,214	26.77	[6] 698,321	15.30	[6] 281,580	28.10	[7] 186,[illegible]
22	12.40	[10] 177,072			22.60	222,080	32.45	[7] 284,[illegible]

31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	31.13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Macoupin	.114	[illegible]	[illegible]	[illegible]	.214	[illegible]	[illegible]	[illegible]

B. AGAR COUNTS

Summit	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Des Plaines	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	473	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Kankakee	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
267	[illegible]	[illegible]			[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fox	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Vermilion	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
170	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mackinaw	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Spoon	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]
Sangamon	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]						
Crooked Creek	[illegible]	[illegible]			.319	[illegible]	.313	[illegible]
78	[illegible]	[illegible]						
77	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]
43	[illegible]	[illegible]	28.77	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
33	[illegible]	[illegible]						
31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Macoupin	.114	[illegible]	[illegible]	[illegible]	.214	[illegible]	[illegible]	[illegible]

See footnotes at end of table.

TABLE No. 49.—*Summary of bacteriological observations at all sampling stations in terms of quantity units*—Continued

[Bacteria per cubic centimeter × discharge in thousands of second-feet. Means for gelatin count, agar count, and B. coli, respectively, for four seasonal periods]

B. COLI

Sampling stations	Summer months		Winter months		Summer transitional (May and October)		Winter transitional (April and November)	
	Discharge	Bacteria	Discharge	Bacteria	Discharge	Bacteria	Discharge	Bacteria
	Second-feet	*Quantity units*	*Second-feet*	*Quantity units*	*Second-feet*	*Quantity units*	*Second-feet*	*Quantity units*
Summit	[illegible]	[illegible]	[illegible]	21,012	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Des Plaines	[illegible]	[illegible]	.814	175	.204	4	1.260	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	42,200	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Kankakee	1.12	[illegible]	[illegible]	[illegible]	2.14	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]			[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	18.20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fox	.46	[illegible]	[illegible]	470	1.07	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Vermilion	[illegible]	[illegible]	1.263	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	11.15	[illegible]	[illegible]	[illegible]	[illegible]	1,229	[illegible]	[illegible]
179	11.50	[illegible]	[illegible]	[illegible]	[illegible]	719	[illegible]	[illegible]
[illegible]	11.67	[illegible]	[illegible]	1,430	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	11.74	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mackinaw	.277	[illegible]	1.071	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	7,251	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Spoon	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]
Sangamon	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]						
Crooked Creek	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	12.10	[illegible]						
77	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	26.77	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]						

31	15.98	[illegible]	30.68	570	34.45	766	54.80	1,900
26	15.98	.70	31.13	[9]436	34.45	604	54.80	[illegible]
Macoupin	.114	23	1.536	44	.214	[illegible]	3.184	838

Observations were not made at certain stations for all months and hence results are not included in computing seasonal averages as follows:

[1] July, 1921.
[2] July, 1921, and July and August, 1922.
[3] July, August, and September, 1921.
[4] October, 1921.
[5] June, July, and August, 1922.
[6] May, 1922.
[7] April, 1922.
[8] August and September, 1921 and June, July, and August, 1922.
[9] January, 1922.
[10] September, 1921, and June, July, and August, 1922.

BACTERIAL POLLUTION OF THE ILLINOIS RIVER

The general extent of bacterial pollution of the Illinois River may be ascertained by an inspection of the analyses presented in the foregoing tables, which may be briefly summarized in yearly average numbers of agar counts at certain stations as follows:

Sampling station	Location	Gelatin count, yearly average (September, 1921, to August, 1922, inclusive)
Summit	Main drainage canal	1,220,000
292	Main drainage canal, Lockport	2,040,000
263	Morris	681,000
166	Above Peoria	14,000
153	Above Pekin	34,800
148	Below Pekin	107,000
26	Kampsville	14,000

The degree of pollution may be gauged more intelligently when a comparison is made with the bacterial content of average sewage. Numbers of bacteria in sewage vary considerably, depending on the age, character, and strength of the sewage under consideration. Metcalf and Eddy [2] state, "It varies from 1,000,000 per cubic centimeter in sewage which is fresh, dilute or affected by the presence of considerable acid or other antiseptic industrial wastes, to perhaps 20,000,000 in very strong sewage or sewage of moderate strength which is sufficiently old to have permitted a large development of bacteria." However, a comparison of the bacterial content of the main drainage canal with that of city sewage as presented in Table No. 50 indicates that, from a bacterial standpoint, they are quite similar.

TABLE No. 50.—*Comparison of bacterial content of main drainage canal with domestic sewage*

Source of sewage	Bacteria per cubic centimeter gelatin, 20° C.	Reference
Main drainage canal station 292.0	2,040,000	----------
Lawrence, Mass	2,095,600	(a)
Columbus, Ohio	3,600,000	(b)
Gloversville, N. Y	1,600,000	(c)
Philadelphia, Pa	3,000,000	(c)
Cincinnati, Ohio	2,332,000	(d)
Average	2,525,000	----------

[a] Metcalf & Eddy, American Sewerage Practice, Vol. III, p. 741.
[b] Geo. A. Johnson, Report on Sewage Purification of Columbus, Ohio, 1905, p. 53.
[c] Metcalf & Eddy, American Sewerage Practice, Vol. III, p. 88.
[d] U. S. Public Health Service, Walnut Street Sewer, Cincinnati. Average of weekly samples during period of 1 year, unpublished data).

---

[2] Metcalf & Eddy, American Sewerage Practice, Vol. III, p. 739.

The bacteria generally tend to increase in numbers in the section of the drainage canal below Summit, reaching a maximum at station 292. Below this point and the junction of the canal with the Des Plaines River the pollution is severe, extending throughout the zone to station 263 at Morris, decreasing quite rapidly in summer but generally increasing in the winter months. By the time the water has reached station 166 at Peoria, a marked reduction has occurred which is consistent throughout the year. Due to the contribution of Peoria wastes the count is greatly increased at station 153 and is generally even greater at station 148, decreasing then to a reasonably low concentration at Kampsville. At station 26, the lowest point of the river from which samples were collected, the bacterial pollution is quite comparable with that of the Mississippi River as indicated from routine samples collected at Hamberg, 38 miles above the mouth of the Illinois.

The tributaries of the Illinois are consistently less polluted than the main stream, so that their effect is always that of dilution. During the summer months inflow from tributaries is comparatively small, however, so that during this critical period their contributions produce little effect.

From such a considerable volume of bacteriological analyses some general observations are of interest as indicating the relationships existing between the various groups of bacteria as enumerated on different media, the changes induced by seasonal temperatures and the correlation of numbers of bacteria in the stream with the numbers of persons contributing sewage.

RELATION BETWEEN GELATIN, AGAR, AND B. COLI COUNTS

The relative numbers of bacteria determined by the use of various kinds of media seem to vary quite considerably with seasonal temperature, as was observed in the Ohio River studies. These changes are illustrated in the following tables (Nos. 51, 52, and 53) in which the ratios of gelatin to agar counts, agar to *B. coli*, and gelatin to *B. coli* are given for representative sampling stations for each month during which the field studies were in progress.

RATIO OF 20° GELATIN TO 37° AGAR COUNTS

During the summer months, approximately as many bacteria were recorded on the gelatin as on the agar media, the ratio of gelatin to agar counts on the main stream for the sampling stations given ranging from 1.03 to 1.77 and averaging for all the stations 1.23. Similar ratios for tributary streams show the same relative numbers present where the variation is from a maximum of 1.30 to a minimum of 0.92, with the same average of 1.23. However, when winter conditions prevailed, the gelatin colonies greatly exceeded those on agar, and the average ratio for all the given stations on the main stream was 9.41 and for the tributaries 6.62. The transitional periods indicate ratios progressing in orderly arrangement from those of the summer to those observed in the winter season. It is evident then that, as was observed in the Ohio River, the relative numbers of gelatin colonies are much higher in winter than in summer. It may also be observed from Table No. 51 that in winter especially a rather abrupt change in the ratios takes place between stations 166 and 148, the relative numbers of gelatin counts being greatly reduced, possibly caused by the fresh sewage pollution from Peoria which is introduced in this zone. From station 292 to 166 and again from station 148 to 26, during this winter period, this ratio gradually increased as the water passed successive sampling stations, indicating that the 37° C. organisms disappeared at a faster rate than those belonging to the 20° C. group.

TABLE No. 51.—*Ratios of gelatin counts to agar counts (=1) at representative sampling stations on the Illinois River, by months, 1921–22*

Month	Ratio of gelatin count to agar count (=1)												
	292	263	196	166	148	122	26	Kankakee	Fox	Vermilion	Spoon	Sangamon	Macoupin
1921													
July	......	......	1.14	1.56	1.51	1.34	0.94	......	1.50	1.19	2.10	0.60	0.81
August	0.86	......	.69	2.25	1.18	1.26	1.95	1.01	1.43	.73	1.31	1.15	2.02
September	.78	......	.95	1.17	1.10	1.11	1.83	1.17	.99	1.09	.95	1.01	2.40
October	1.28	1.23	1.29	2.00	.76	1.13	2.14	.99	1.78	1.17	1.56	1.20	1.53
November	1.83	1.97	4.06	5.96	1.28	1.66	4.82	1.02	2.82	2.77	2.19	1.25	5.65
December	2.75	3.21	9.89	12.90	3.92	4.11	6.24	2.09	2.91	4.86	2.12	......	17.54
1922													
January	7.25	7.22	19.10	29.17	......	......	......	2.50	7.48	6.08	15.61	......	......
February	8.14	8.00	19.89	3[illegible].36	2.10	5.67	8.49	4.53	11.15	6.41	7.95	......	5.64
March	6.24	6.07	12.60	16.42	2.66	4.32	6.18	3.02	9.81	3.13	5.00	......	5.13
April	6.99	8.15	7.73	6.32	4.76	5.09	1.47	3.23	4.70	3.64	1.72	......	1.72
May	5.48	3.73	2.97	2.26	1.90	2.22	.88	3.02	2.95	3.11	1.89	......	.81
June	1.58	1.37	1.21	2.02	.67	1.01	.90	.61	.73	1.73	1.83	......	.39
July	.98	1.10	.84	2.23	.94	.97	1.55	1.78	1.16	1.52	1.92	......	1.32
August	.95	.88	1.52	1.39	1.01	1.19	1.26	1.31	1.72	1.09	.95	......	.88
Seasonal averages													
Summer	1.03	1.12	1.06	1.77	1.10	1.15	1.40	1.18	1.26	1.23	1.51	.92	1.30
Winter	6.10	6.13	15.37	23.71	2.89	4.70	6.97	3.04	7.83	5.11	7.67	......	9.44
Summer transitional	3.38	2.48	2.13	2.13	1.33	1.68	1.51	2.00	2.37	2.14	1.74	1.20	1.17
Winter transitional	4.41	5.06	5.90	6.14	3.02	3.68	3.15	2.13	3.76	3.20	1.96	1.25	3.68

RATIO OF 20° GELATIN COUNT TO B. COLI

The ratios of gelatin counts to *B. coli* are given in Table No. 52 for the same sampling stations as were the gelatin-agar ratios. As might be expected these latter ratios are not as consistent as are those of gelatin to agar; nevertheless the difference between the summer and winter relationship is plainly evident. Thus for the main river stations given in the table there were during the summer one hundred and ninety-two times as many organisms growing on gelatin at 20° C. as there were *B. coli* found, while for the winter months this figure had increased to 499. Similar ratios for the tributaries show the same general tendency, where the respective figures for summer and winter are 358 and 753. It may be noted too that, in the gelatin-*B. coli* ratios, the relative numbers of the gelatin count become larger at successive downstream sampling stations below Lockport until the relationship is disturbed below station 166 by the addition of Peoria sewage entering above station 148, after which time the increase again becomes effective.

TABLE NO. 52.—*Ratios of gelatin counts to B. coli counts (=1) at representative sampling stations on the Illinois River, by months, 1921–22*

Month	Ratio of gelatin count to B. coli (=1)						
	292	263	196	166	148	122	26
1921							
July	....	....	228	1,070	84.25	267	719
August	73.02	....	102	225	192	124	132
September	86.26	....	143	256	114	110	138
October	96.08	35.08	111	107	55.12	78	303
November	82.40	71.70	179	232	145	151	302
December	68.84	225	282	280	283	150	691
1922							
January	159	250	284	302	....	....	....
February	128	251	480	622	171	415	3,286
March	98.02	267	587	1,111	158	146	1,286
April	125	188	235	569	115	513	290
May	80	51.21	607	144	259	290	391
June	50.18	49.25	47.01	137	64.68	56.19	273
July	32.08	58.07	198	396	117	102	422
August	110	79.25	411	322	33.62	213	516
Seasonal averages							
Summer	70.23	62.19	198	401	101	146	267
Winter	113	250	358	579	304	237	1,750
Summer transitional	87.54	43.14	359	126	157	174	347
Winter transitional	104	130	207	400	130	232	298

Month	Ratio of gelatin count to B. coli (=1)					
	Kankakee	Fox	Vermilion	Spoon	Sangamon	Macoupin
1921						
July	....	108	198	725	155	54.58
August	208	223	276	415	95.26	152
September	165	644	262	256	111	129
October	51.07	472	32.70	163	71.23	128
November	133	57.11	124	409	157	302
December	61.98	56.87	262	643	....	1,040
1922						
January	647	209	185	2,029	....	....
February	367	1,030	386	898	....	1,570
March	589	883	78	702	....	1,340
April	331	59.18	145	218	....	218
May	494	81.22	153	218	....	354
June	55.07	911	183	185	....	317
July	723	202	155	289	....	740
August	3,170	20.53	58.76	65.87	....	305
Seasonal averages						
Summer	864	308	180	322	120	283
Winter	416	694	263	1,070	....	1,320
Summer transitional	272	276	92.85	200	71.23	241
Winter transitional	232	56.14	134	344	157	260

RATIO OF 37° AGAR COUNT TO B. COLI

The agar-*B. coli* ratios for representative sampling stations are shown by months in Table No. 53. Here the differences between summer and winter ratios are not quite so marked, the summer agar counts for the main river stations averaging one hundred and fifty-seven times the *B. coli* in summer and sixty-five times in winter. It would appear that the agar group as a whole is more sensitive to temperature changes than is that of the *B. coli* since relatively fewer numbers appear during the cold-weather months.

TABLE No. 53.—*Ratios of agar counts to B. coli counts (=1) at representative sampling stations of the Illinois River, by months, 1921–22*

Month	Ratio of agar count to B. coli=(1)												
	292	263	196	166	148	122	26	Kankakee	Fox	Vermilion	Spoon	Sangamon	Macoupin
1921													
July	......	......	201	684	55.94	200	702	......	72.10	167	345	200	67.40
August	84.47	62.08	235	100	163	95.20	67.94	206	156	378	317	82.65	75.13
September	111	71.83	150	218	103	99.44	75.91	141	652	240	297	111	53.64
October	74.43	28.47	86.30	53.44	72.18	66.90	142	51.79	265	27.86	116	59.24	82.58
November	44.90	36.80	44.20	38.83	113	90.68	62.63	130	20.25	44.59	214	125	53.50
December	24.97	70.08	28.51	29.45	72.27	36.40	111	29.62	19.21	61.91	303	......	56.44
1922													
January	21.95	35.83	14.90	10.38	14.46	28.72	387	289	28.15	30.74	130	......	......
February	15.75	31.34	24.12	14.36	81.61	73.15	......	81.06	146	60.19	113	......	278
March	15.70	44	30.67	67.69	59.16	33.85	208	195	90	56.94	140	......	260
April	17.88	23.11	30.42	90	24.27	90	198	102	12.58	39.78	127	......	127
May	14.59	13.71	20.40	63.91	137	121	444	164	27.56	49.19	116	......	435
June	31.69	36.01	38.80	67.86	74.35	57.00	303	89.73	1,290	106	101	......	809
July	32.54	82.74	235	178	124	105	272	405	261	102	151	......	663
August	116	80.90	270	231	38.19	179	412	2,420	11.91	54.07	69.06	......	346
Seasonal averages													
Summer	75.14	62.51	198	246	92.25	123	315	652	402	175	208	151	319
Winter	19.59	45.31	24.56	30.46	56.88	45.55	235	141	70.84	52.46	171	......	199
Summer transitional	44.51	21.09	53.40	58.68	104	94.98	250	108	146	38.52	116	59.24	259
Winter transitional	31.39	29.98	37.31	64.42	68.64	90.34	130	116	16.42	42.18	170	125	90.25

SEASONAL CHANGES IN BACTERIAL CONCENTRATION

There is a marked seasonal variation in the bacterial content at all sampling stations throughout the stream, as may be observed from an inspection of Table No. 46. Thus, at station 292 the gelatin count ranges from an average concentration of 3,310,000 in summer to one of 579,000 in winter, or in the ratio of 5.71 to 1; the agar counts for the same periods change in the ratio of 29.7 to 1, while the *B. coli* ratio is 10.2 to 1. At successive downstream stations these ratios change quite consistently to lower values, as may be noted from the data of Table No. 54, until station 153 is reached, where an increase may be noted which reaches a second maximum at station 148, the zone in which the sewage of Peoria is effective. Below station 148 the ratios again decrease quite consistently.

TABLE No. 54.—*Seasonal variation in bacterial content*

Station	Ratio of summer to winter concentration of bacteria			Station	Ratio of summer to winter concentration of bacteria		
	Gelatin at 20° C.	Agar at 37° C.	B. coli		Gelatin at 20° C.	Agar at 37° C.	B. coli
292	5.71	29.70	10.20	166	0.16	2.02	0.23
266	2.42	12.40	7.10	153	1.24	4.62	1.76
263	1.31	7.66	6.01	148	9.70	77.00	25.70
240	1.70	10.6	5.10	123	3.05	15.30	6.74
227	.36	3.05	1.43	43	.66	.36	5.33
196	.71	9.96	1.32	14	.42	2.21	3.09
179	.35	.95	1.56	26	.44	2.32	4.06

A more direct comparison of seasonal changes in bacterial numbers may be made by referring to the quantity unit tabulations of bacterial pollution at all sampling stations summarized in Table No. 49. It may be inferred that such seasonal fluctuations in concentration are not the result solely of variations in dilution, since the volume of flow through the main drainage canal is relatively uniform. Moreover, since the contributing population must be assumed to remain practically constant from season to season, it would appear that the per capita contribution of bacteria, as measured in the receiving stream, is subject to a considerable seasonal fluctuation. Similar variations in bacterial contributions from sewered populations were also observed in the Ohio River. For purposes of comparison, the ratios of average summer to winter quantity units of bacteria found at representative sampling stations below large cities are given in Table No. 55.

TABLE No. 55.—*Seasonal fluctuation in quantity units of bacteria in Ohio and Illinois Rivers below major sources of pollution*

Sampling station	Below city of—	Ratio of summer to winter quantity units of bacteria		
		Gelatin	Agar	B. coli
Illinois River:				
292	Chicago	7.9	29.8	10.5
148	Peoria	5.3	15.6	11.4
Ohio River:[1]				
475	Cincinnati	5.5	18.3	4.9
619	Louisville	1.8	17.5	1.5

[1] Data from Tables Nos. 100, 101, and 102, Public Health Bulletin 143.

RELATION OF BACTERIAL POLLUTION TO SEWERED POPULATION CONTRIBUTING

A comparison of the maximum numbers of quantity units of bacteria observed, resulting from the known sewered population served by the main drainage canal, affords a ready means of computing the per capita contribution of bacteria. It should be noted that the point of such maximum bacterial density does not occur immediately below the sewer outlets but at a place corresponding to from 10 to 20 or 25 hours below the entrance of pollution. Thus during the summer months the maximum bacterial content resulting from the Chicago sewage was observed at station 292 above Joliet. During the winter months this maximum had apparently moved downstream to station 263. Taking these maxima of bacterial contents, in terms of quantity units, there has been computed for each seasonal period the per capita quantity units of bacteria contributed by the population of Chicago based on (*a*) the actual sewered population, and (*b*) the total equivalent population, consisting of actual population plus equivalent population of industrial wastes. (See Table No. 56.)

TABLE NO. 56.—*Bacterial pollution (in quantity units) per capita in Illinois River, contributed to the main drainage canal and Illinois River*

Season	Maximum quantity units in stream				Quantity units per capita contributed by—					
					(a) Actual population			(b) Equivalent population		
	Occurs at station	Gelatin	Agar	B. coli	Gelatin	Agar	B. coli	Gelatin	Agar	B. coli
Summer	292	28,670,000	29,440,100	501,369	10.116	10.338	0.1769	6.074	6.237	0.1062
Winter	263	11,969,000	2,358,100	48,324	3.980	.7842	.0161	2.433	.4795	.0098
Summer transitional	292	26,817,200	12,325,800	310,602	9.463	4.349	.1096	5.682	2.611	.0658
Winter transitional	292	9,312,000	2,859,760	90,220	3.285	1.009	.0318	1.973	.6059	.0191

Actual sewered population above station 292	2,834,351
Industrial equivalent population above station 292	1,885,600
Total equivalent population	4,720,000
Actual sewered population above station 263	3,006,588
Industrial equivalent population above station 263	1,911,320
Total equivalent population	4,918,000

The same data may be expressed in terms of bacteria per day per capita by remembering that one quantity unit is equal to 2,446.589 billions of bacteria per day.

A similar computation of the per capita contribution of bacteria may be made for the population of Peoria by noting the increase in quantity units between station 166, immediately above, and station 153, about 10 miles below the city. For purposes of comparison, data are available from the cities of Cincinnati and Louisville on the Ohio River, which are not widely different from those on the Illinois. These unit figures for the four cities of Chicago, Peoria, Cincinnati and Louisville are given in Table No. 57, and the corresponding seasonal averages computed in each case to obtain a general average of the per capita contribution of bacteria to streams from sewered communities.

Table No. 57.—*Seasonal changes in numbers of bacteria added to streams by sewered populations of Cincinnati, Louisville, Chicago, and Peoria*

Added by—	Quantity units of bacteria per capita			Billions of bacteria per capita per day		
				Growing on—		
	Gelatin	Agar	B. coli	Gelatin at 20° C. for 48 hours	Agar at 37° C. for 24 hours	B. coli
Chicago:						
Summer	10.116	10.388	0.177	24,750	25,415	433
Winter	3.980	.784	.016	9,737	1,918	39
Peoria:						
Summer	6.447	10.480	.0942	15,773	25,640	231
Winter	.869	3.125	.0577	2,126	7,646	141
Cincinnati:						
Summer	5.764	7.486	.230	14,102	18,314	563
Winter	1.036	.410	.0486	2,535	1,003	119
Louisville:						
Summer	5.544	6.475	.1189	13,564	15,842	291
Winter	3.008	.3707	.0789	7,359	907	193
Averages:						
Summer	6.966	8.707	.1088	17,043	21,302	266
Winter	2.229	1.172	.0503	5,452	2,867	123

Note.—One quantity unit=2,446.589 billions of bacteria per day.

NATURAL PURIFICATION

An inspection of the data of Table No. 49 indicates that natural purification, as measured by the decrease in bacteria as the water passes downstream, is sharply interrupted by the contribution of pollution of the Peoria district immediately below station 166. It is advisable therefore to consider the upper and lower river separately since the change thus effected is sufficient to mask the continuing decrease in the bacterial content originally present above Peoria.

With this division in mind, there is observed during the summer months a progressive decrease in all bacterial counts from station 292 to 166. Below Peoria the counts increase from station 153 to 148 and then systematically decrease in numbers to station 26. In winter, however, there is no regular decrease but rather an increase from station 292 to station 263 after which a consistent reduction occurs. Below Peoria natural purification during this period is masked by the relatively large contributions of tributaries with their burdens of surface soil wash. The extent of such added pollution was not in all cases determined, due to the discontinuance of one of the branch laboratories.

While a simple inspection shows this general tendency toward a progressive reduction in bacterial content in both the upper and lower rivers, the evaluation of this effect is complicated by other factors introducing changes in the stream such as additional inflow from tributaries and the discharge of sewage and industrial wastes from intermediate communities. Moreover, in the upper river the observed changes are further complicated because of the variations from hour to hour both in volume and concentration of sewage pollution from the main drainage canal. In order to determine the extent to which such factors influence the observed rates of purification, corrections for their effect are considered for the upper and lower Illinois River separately.

UPPER ILLINOIS RIVER

The important tributaries of the upper Illinois or those having drainage areas of 1,000 square miles or over, are the Des Plaines, Kankakee, Fox, and Vermilion, with a combined flow which averaged 738 second-feet in summer and 10,500 second-feet during the winter months. The entire increase in volume of discharge of the main river between stations 292 and 166 was 2,960 second-feet in summer and 12,450 second-feet in winter, so that these principal tributaries, all of which were rated and examined, contributed 25 per cent of the total inflow in summer and 84 per cent in winter.

The influence of a tributary may be either to increase or diminish the density of bacteria, but must always increase the quantity units or absolute numbers of bacteria. Reference to Table No. 47 shows that all the tributaries of the upper Illinois are less grossly polluted than are the waters of the main stream and hence tend to decrease the concentration by dilution. When converted to quantity units their effect is comparatively small, usually less than 1 per cent, except during the winter months. These tributary contributions as measured by the agar counts for the various seasonal periods are as follows:

Per cent by which pollution (in quantity units) of upper Illinois River is increased by principal tributaries

Tributary	Summer	Winter	Summer transition	Winter transition
Des Plaines	0.0092	3.15	0.0068	0.32
Kankakee	.049	4.75	.28	4.86
Fox	.18	3.82	.72	.95
Vermilion	.16	2.16	.25	1.90

The population in cities located along the upper Illinois River, while not extensive, is sufficient to produce a measurable effect on an unpolluted stream of this size, although due to the excessive burden from the drainage canal, the change in passing any of the cities is scarcely discernible. Most of the cities are largely residential or at least are engaged in industries that do not contribute excessive amounts of industrial wastes. It is possible to estimate the effect of this intermediate population in terms of bacterial pollution, assuming that the per capita contribution is the same as that of Chicago as derived in Table No. 56. By this method the net change effected in the river by each principal city is presented in the following table, No. 58:

TABLE No. 58.—*Estimated pollution added by principal cities along the upper Illinois River as measured by bacteria growing on agar at 37° C. and expressed in per cents of quantity units present in the stream at station next above*

Town	Located at station (miles from mouth)	Equivalent population (sewered plus industrial waste)	Quantity units of pollution		Amounts added in terms of percentage present at station next above	
			Summer	Winter	Summer	Winter
Joliet	288	50,727	316,384	24,324	1.10	1.78
Morris	263	26,651	192,416	14,790	1.73	.63
Marseilles	247	104,090	640,184	40,930	8.97	2.12
Ottawa	237	12,100	76,093	5,845	1.64	1.28
La Salle and Peru	222	20,112	120,429	9,642	12.65	1.60
Spring Valley	218	4,795	28,830	2,997	3.90	.36
Lacon	189	440	2,994	230	.47	.19

From these estimates it is evident that the contributions from both tributaries and cities are relatively small and unimportant and, considered singly, not of sufficient magnitude to justify being corrected for. The effect of successive additions of pollution is, however, cumulative on the observed results of the lower stations, and for this reason they are applied in the form of corrections to obtain the net rates of change in the pollution at successive sampling stations.

Since it is evident that the bacterial content of the main river is tending to decrease as the water flows downstream, it is to be presumed that similar bacteria added by tributary inflow or by the discharge of sewage from a sewered community tend likewise to decrease. Whether the decrease in such contribution proceeds at the same or at a different rate than that of the main stream is not directly ascertainable, but in the absence of specific information it seems reasonable to assume that the rates are similar. Such an assumption is the only justifiable one which offers a practical method for applying a correction to the observations at successive sampling stations.

For the purpose of applying specific corrections for the bacteria added by tributary inflow and by sewage and industrial wastes, certain assumptions are necessary:

(*a*) That these bacteria are added at a point immediately below the nearest sampling station on the main stream, which is not always literally true.

(*b*) That after entering the main stream the bacteria thus contributed follow the same proportional rates of change in numbers as do the bacteria previously present; that is, the ratio of bacteria added at any point to those already present will remain constant throughout the course of the stream below.

For example, if the main stream, having a total of 90,000 quantity units, receives a tributary with 10,000 similar units, then the tributary contribution is 10 per cent of the total at all points below the junction. If at a lower point the total quantity units are determined to be 50,000, then on this assumption 10 per cent of this total, or 5,000 quantity units, represents the bacteria remaining originally received from the tributary and the difference or 45,000, the number present in the main stream independent of the tributary.

If, now, immediately below this second point a second tributary enters, carrying 10,000 quantity units of bacteria, raising the total to 60,000, then the relative numbers from the different sources will be:

Main stream, 45,000 = 75 per cent;
Tributary A, 5,000 = 8.33 per cent;
Tributary B, 10,000 = 16.67 per cent;

and these relative proportions will (under the assumption made) continue regardless of the extent of natural purification which may take place until some further inflow is received.

The adjustment of observations on the main stream to eliminate the effect of contributions from the tributaries is perhaps most conveniently done by developing a series of correction factors to be applied to the observations at corresponding sampling stations. Thus below tributary A, where the total quantity units are 100,000, the contribution of the main stream is 0.90 of the total, which ratio is constant at all successive sampling stations until tributary B is reached, and the application of the factor 0.90 to quantity unit observations from stations between A and B will give the pollution chargeable to the main stream. Below tributary B, where 10,000 quantity units are added to an observed total of 50,000, the ratio of the quantity units above this second contribution to the total below is

$$\frac{50,000}{60,000} = 0.833$$

Since only 0.90 of the quantity units above the junction with tributary B came from the main stream, of the observed quantity units below tributary B, 0.90 × 0.833 = 0.75 will have come originally from this source. Therefore the combined factor of 0.75 should be applied to observed quantity units of bacteria in the main stream below tributary B to correct for the combined influence of tributaries A and B. This procedure may be continued for any additional number of tributaries which may come in, the correction factors being cumulative. Obviously this same principle is applicable to corrections for contributions of sewage from cities, provided such addition can be stated in terms of quantity units.

Table No. 59 illustrates this method used in deriving correction factors to be applied to the observed gelatin counts, expressed in quantity units, at successive sampling stations. Table No. 60 shows the factors similarly derived for gelatin and agar counts and *B. coli*, in the upper river, for the four seasonal periods into which the data have been grouped for study.

Concerning these corrections it should be noted that, especially in summer, they are of minor importance at most stations, certainly too small to be significant or permissible as corrections to data which are probably in error by 10 per cent or more. They are therefore applied only because of their bearing upon stations farthest downstream. Furthermore, the corrections for cities assume that their sewage comes in immediately below a sampling station and that the maximum effect of such contribution is immediately realized. The maximum effect may actually take place some time later, perhaps 12 to 15 hours, though this is not certain. At best the estimate of quantity units of bacteria contributed by sewered population can be considered to be only roughly approximate and accordingly such corrections as herein developed, although doubtless in the right direction, must be considered to be subject to an appreciable probable error.

TABLE No. 59.—*Derivation of correction factors for quantity units of bacteria added by tributaries and cities—Summer gelatin*

Sampling station	Tributary or city	Quantity units				
		In main stream (a)	Added by tributary or city (b)	Total below junction (a+b=c)	Ratio (a÷c=d)	Correction factor to be applied
293		28,000,490		28,310,870	0.988807	1
	Des Plaines		2,385			
	Joliet		300,118			
288		18,8[illegible]		18,8[illegible]	1	.99[illegible]
286		13,467,700		13,476,670	.999334	.99[illegible]
	Rockdale		8,971			
278		12,367,300		12,373,580	[illegible]	[illegible]
	Kankakee		6,282			
260		10,040,000		10,[illegible]	[illegible]	.987870
	Morris		187,290			
247		7,[illegible],670		8,170,000	[illegible]	.97[illegible]
	Marseilles		6[illegible],219			
240		5,472,040		5,[illegible],910	.984726	[illegible]
	Ottawa		74,936			
	Fox		10,828			
227		1,318,180		1,4[illegible],310	[illegible]	[illegible]
	Vermilion		1,981			
	La Salle, Peru, and Spring Valley		151,239			
198		726,953		729,[illegible]	[illegible]	[illegible]
	Lacon		2,916			
179		271,9[illegible]		271,9[illegible]	1	[illegible]
166		55,086		55,086	1	[illegible]

TABLE No. 60.—*Correction factors for observed quantity units of bacteria added by tributaries and cities*

Sampling station	Gelatin	Agar	B. coli	Gelatin	Agar	B. coli
	(a) Summer season			(b) Winter season		
292	1	1	1	1	1	1
288	.980037	.998733	.999033	.951022	.945066	.963085
286	.999857	.999733	.994031	.951022	.945066	.959064
279	.999270	.999410	.999066	.951340	.945167	.995430
263	.987979	.987989	.999072	.980122	.992346	.999020
247	.979792	.971077	.971340			
240	.895669	.891193	.874541	.910724	.878151	.944066
227	.881989	.872275	.838090	.887126	.835770	.904097
198	.790039	.759010	.790043	.872363	.803804	.913775
179	.769804	.752286	.789764	.871884	.802109	.912884
166	.769804	.752286	.789764	.871884	.802109	.912884
	(c) Summer transitional season			(h) Winter transitional season		
292	1	1	1	1	1	1
288	.990074	.999090	.990111	.980380	.983834	.984879
286	.990074	.999090	.990111	.980380	.983834	.984879
279	.988437	.999495	.986763	.989255	.983456	.989375
263	.985760	.985720	.999180	.960770	.990721	.959892
247	.945287	.953885	.970112			
240	.901827	.873077	.889878	.932768	.910519	.894402
227	.874157	.868828	.819913	.899411	.909984	.914423
198	.809716	.807049	.849758	.895473	.887164	.989946
179	.803600	.802984	.834850	.895401	.885573	.984919
166	.803600	.802984	.834850	.895401	.885573	.984919

VARIATIONS IN VOLUME AND CONCENTRATION OF FLOW OF MAIN DRAINAGE CANAL

Intradiurnal variations in the volume and concentration of flow from the main drainage canal are of sufficient magnitude to distort the gross rate of purification as defined by results of averages of only one sample each day collected from the various fixed sampling points throughout the course of the river. Since it was not possible to collect composite samples at each sampling station and, furthermore, was necessary to collect all samples during the morning hours, obviously the same portion of water was not sampled as it passed each successive sampling station. Hence it is entirely possible that a direct comparison of the results would not be an accurate measure of the bilogical change occurring between sampling stations.

Due to the varying load carried by the power plant located at the end of the main drainage canal at Lockport, the rate of flow through the channel is not constant throughout the 24-hour period but varies from hour to hour. Since most of the flow of the upper Illinois is made up of the discharge from the drainage canal, the same fluctuations are noticeable at the sampling stations on the main stream.

The fluctuations in the daily discharge of the main drainage canal are shown by the continuous records of gauge height at Jackson Street Joilet, as registered by the automatic (Gurley) recording gauge of the United States Geological Survey, located at that place. A tabulation of bihourly gauge heights was prepared by using the actual readings recorded during a period of a week in each month of the year. From this tabulation the average bihourly gauge heights and corresponding discharges, for both summer and winter periods, were derived. These average changes in gauge height and discharge are given in Table No. 61 and illustrated graphically in Figure 17.

TABLE No. 61.—*Average gauge height and discharge at station 288.4*

[Data from records of United States Geological Survey]

Time	Summer		Winter	
	Gauge height	Discharge	Gauge height	Discharge
	Feet	*Second-feet*	*Feet*	*Second-feet*
Midnight	6.18	12,144	5.78	11,070
2 a. m.	6.18	12,144	5.64	10,700
4 a. m.	5.00	9,200	5.57	10,545
6 a. m.	3.69	6,500	5.14	9,522
8 a. m.	4.32	7,742	4.12	7,340
10 a. m.	4.43	7,973	4.64	8,414
12 noon	4.26	7,620	4.41	7,932
2 p. m.	4.22	7,540	4.03	7,160
4 p. m.	3.55	6,235	3.91	6,920
6 p. m.	2.99	5,182	4.40	8,100
8 p. m.	4.66	8,456	5.79	11,095
10 p. m.	6.05	11,780	5.91	11,[illegible]06

This fluctuation of flow in the canal has the further effect of varying the amount of the diluting water withdrawn from Lake Michigan and hence of changing the concentration of the mixture of sewage and lake water. Variations in the volume and strength of domestic and industrial sewage discharged at different times during the day likewise tend to modify from hour to hour the concentration of waste constituents carried by the waters of the drainage canal. This resulting cyclic variation is best shown by observations on the oxygen demand of samples collected from station 292 at four-hour intervals day and night during September and October, 1922.[3] The average 5-day oxygen demand results are shown in Table No. 62.

TABLE No. 62.—*Fluctuations in oxygen demand at station 292 at various times of day*

Time of day	4 a. m.	8 a. m.	Noon	4 p. m.	8 p. m.	Midnight	Daily average
Number of analyses	28	40	40	39	40	28	45
Average oxygen demand, parts per million	10.88	12.44	15.84	16.35	13.75	11.16	13.63
Per cent of daily average	79.88	91.26	116.27	119.15	100.88	81.88	100.00

The fluctuation of the oxygen demand, in terms of per cent of the 24-hour average as above derived is shown graphically in Figure 18.

Additional observations of oxygen demand, and of bacterial content at station 288 were made on one day of each month at 8 and 11 a. m.

---

[3] These samples were collected and analyzed by the Sanitary District of Chicago in their laboratory located at Lockport and under the supervision of their chief chemist, F. W. Mohlman.

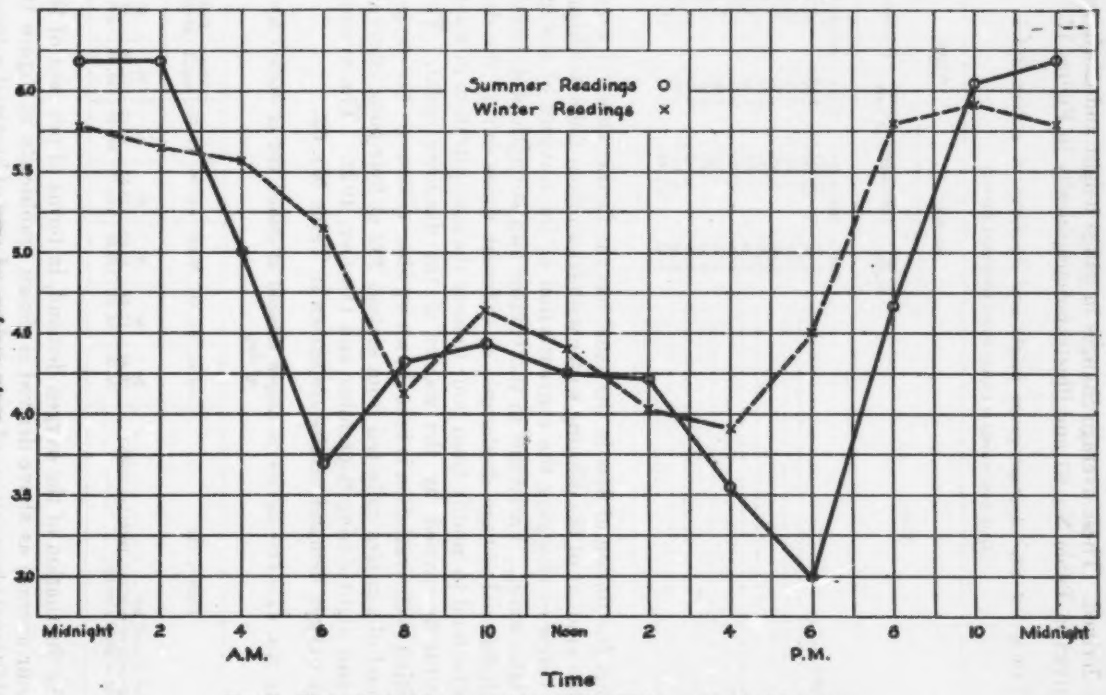


FIG. 17.—Fluctuation in daily gauge height at station 288.4, summer and winter seasons

and at 2, 5, and 8 p. m. These results are presented in Tables Nos. 63, 64, and 65 as referred back to the times when the water represented by these samples passed station 292. Reference to Table No. 62 and the accompanying figure indicates that the average concentration of oxygen demand for the 12 hours, 6.7 a. m. to 6.7 p. m., is 107.5 per cent of the 24-hour average. Hence in Tables Nos. 63, 64, and 65 the percentages of the 12-hour average are transferred to the base of 107.5 per cent in order to make them comparable with the data shown in Table No. 62. As shown in Figure 19, these observations at station 288 indicate that the fluctuations at that place in oxygen demand and in bacterial counts followed substantially the same cyclic change as did the oxygen demand at station 292.

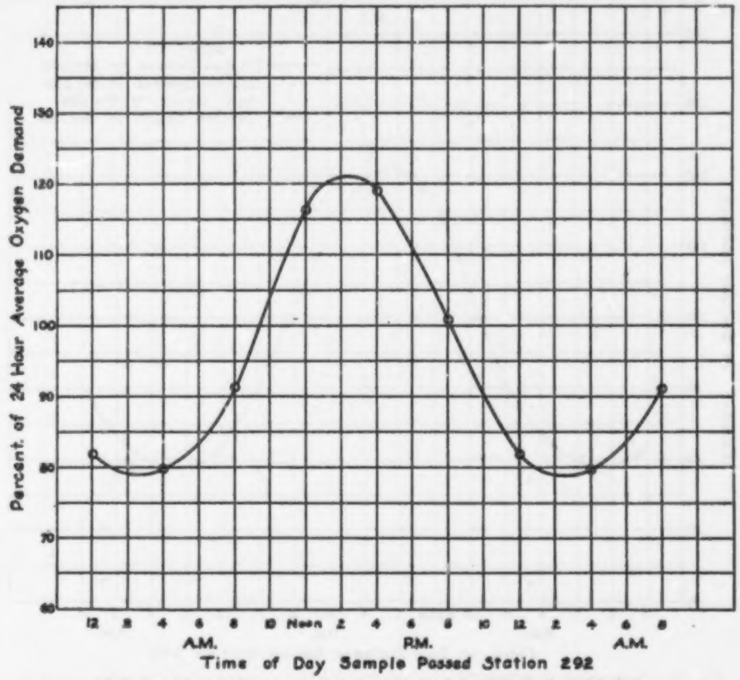


FIG. 18.—Fluctuation in oxygen demand at station 292 throughout the day

Observations similar to those made at station 288 were also made 122 miles downstream at station 166, just above Peoria. These showed no consistent and significant variations from hour to hour. Hence it may be inferred that the "pulses" in sewage concentration so distinctly noticeable at stations 292 and 288 have been eliminated during the time of flow of about 185 hours required to reach station 166. No definite measure is available of the decrease in fluctuation of sewage strength as the water passed successive sampling stations downstream. It seems reasonable to suppose, however, that some such progressive leveling of peaks is occurring, caused by obstructions in the channel, such as bends, dams, and changes in contour of the river bed, all of which conditions preclude the regular mass movement of flow throughout the cross section of the stream.

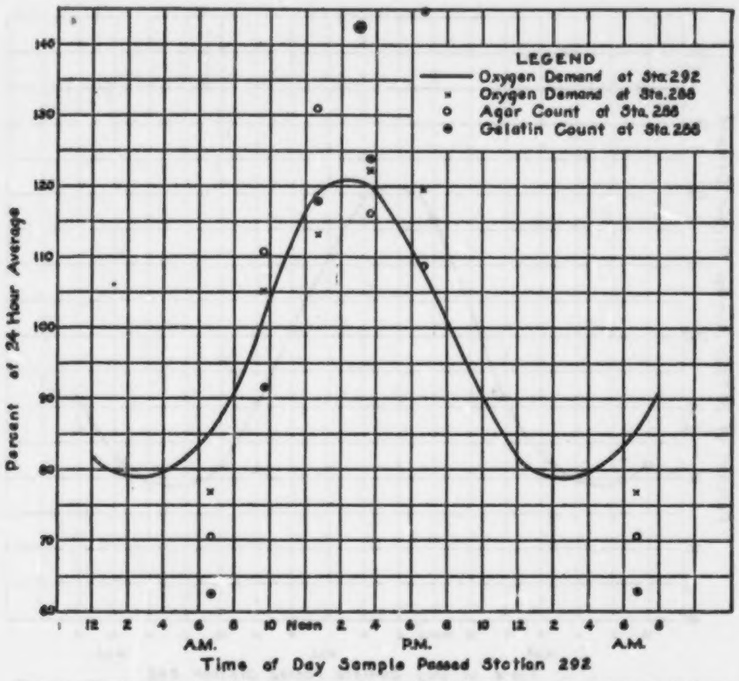


FIG. 19.—Fluctuations at station 288 of oxygen demand and bacterial counts, in terms of 24-hour average, compared with fluctuation in oxygen demand at station 292

TABLE No. 63.—*Daily fluctuation in oxygen demand at station 288*

Date	Oxygen demand in percentage of 12-hour average at times sample passed station 292.0					Average, 6.7 a. m. to 6.7 p. m.	Average oxygen demand (parts per million)
	6.7 a. m.	9.7 a. m.	12.7 p. m.	3.7 p. m.	6.7 p. m.		
Sept. 13	76.2	114.0	102.5	107.0	100.8	100	17.52
Oct. 11	83.7	83.4	95.2	116.2	121.2	100	16.08
Nov. 8	70.6	105.0	99.4	100.0	125.8	100	12.25
May 9	61.6	88.0	96.6	124.2	125.8	100	14.21
June 16	59.8	99.2	116.0	122.0	102.2	100	18.50
July 11	77.3	97.6	121.2	113.8	92.0	100	18.09
Average	71.5	97.9	105.2	113.9	111.3	100	....
Per cent of 24-hour average	76.9	105.2	113.1	122.4	119.6	107.5	....

TABLE No. 64.—*Daily fluctuation in gelatin counts at station 288*

Date	Gelatin counts in percentage of 12-hour average at times sample passed station 292.0					Average per cent 6.7 a. m. to 6.7 p. m.	Average count during day
	6.7 a. m.	9.7 a. m.	12.7 p. m.	3.7 p. m.	6.7 p. m.		
Sept. 13	29.2	115.0	118.0	91.0	145.8	100	2,084,000
Oct. 11	87.7	107.1	118.4	100.2	114.6	100	2,474,000
Nov. 8	35.9	69.8	99.8	116.8	179.5	100	932,000
May 9	26.4	30.4	82.0	168.2	191.3	100	2,300,000
June 16	54.0	105.2	101.8	119.9	118.2	100	2,570,000
July 11	90.3	80.8	136.0	100.6	93.0	100	3,080,000
Aug. 8	82.4	88.3	117.8	111.2	101.5	100	2,300,000
Average	58.0	85.2	109.8	115.4	134.8	100	....
Average per cent of 24-hour average	62.4	91.6	118.0	124.0	144.9	107.5	....

TABLE No. 65.—*Daily fluctuation in agar counts at station 288*

Date	Agar counts in percentage of 12-hour average at times sample passed station 292.0					Average per cent 6.7 a. m. to 6.7 p. m.	Average count during day
	6.7 a. m.	9.7 a. m.	12.7 p. m.	3.7 p. m.	6.7 p. m.		
Sept. 13	76.6	135.1	120.2	89.3	78.3	100	1,500,000
Oct. 11	74.0	148.0	162.7	49.7	66.2	100	1,060,000
Nov. 8	48.8	88.0	99.3	151.5	112.0	100	614,000
May 9	30.5	33.9	101.2	166.0	169.5	100	267,000
June 16	64.0	127.9	100.2	118.0	90.2	100	1,396,000
July 11	87.5	96.2	119.0	97.0	....	100	3,375,000
Aug. 8	78.0	92.7	151.1	85.3	92.0	100	3,036,000
Average	65.6	103.1	121.9	108.1	101.3	100	....
Per cent of 24-hour average	70.5	110.8	131.0	116.2	108.9	107.5	....

It is clear that, in view of these fluctuations, the bacteria passing station 292 at any given hour do not necessarily represent the average for the day. The average for the entire 24-hour period may be calculated, however, from observations made at any hour by applying a correction factor derived from the indicated fluctuations in discharge and sewage strength as cited above. This correction is best applied to the observed quantity units of bacteria which are the product of numbers of bacteria per cubic centimeter and discharge in thousands of second-feet. The factor is derived by determining the ratio which the discharge at any given hour bears to the mean for the day (see fig. 20) and also ascertaining the ratio which the concentration (or numbers of bacteria per cubic centimeter) at that hour bears to the daily average; then the product of these two ratios is obviously the ratio which the quantity units at that hour bears to the average for the day. The reciprocal of this product is then the correction factor to be applied to the observed quantity unit value to derive the average quantity unit figure desired. For example, at 8.67 a. m., the mean time at which samples from station 292 were collected in summer, the discharge, according to the curve shown in Figure 20, is $\frac{82}{100}$ of the daily average. The concentration at this hour from

Figure 18 is $\frac{95}{100}$ of the average daily concentration. The quantity units, therefore, bear to the daily average the ratio of the product of $\frac{92}{100}$ and $\frac{95}{100}$ or $\frac{87}{100}$. Hence the

$$\frac{\text{daily average}}{\text{observed average}} = \frac{100}{87} = 1.15$$

or daily average = observed average × 1.15.

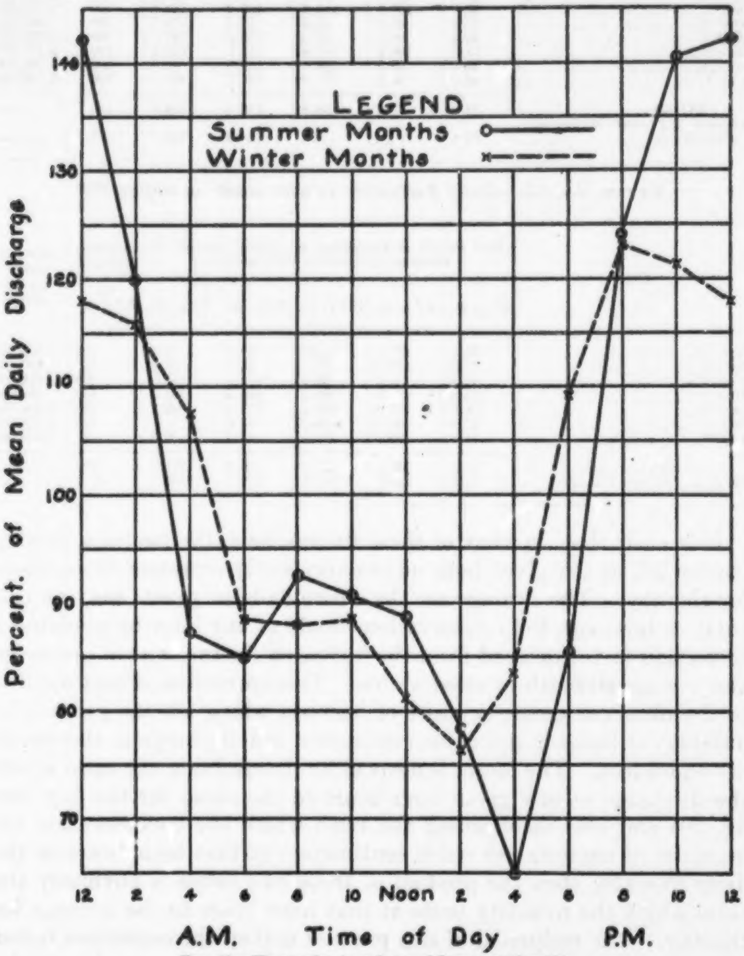


FIG. 20.—Fluctuation in volume of flow at station 292

Corrections thus derived are of considerable magnitude, and, since they effect an adjustment of observations at different stations to a comparable basis, it would seem quite proper that they be applied. However, since the fluctuations in discharge and concentration which are observed at station 292 are no longer observed at station 166, it is necessary to assume some rate at which they decrease between these two stations. No observations are available which would indicate the rate at which this obliteration proceeds or the point at which they have become insignificant. Accordingly, the assumption has been made that the fluctuations have become negligible at station 179 and that between station 292 and this point the hour-to-hour variations above and below the average have diminished in a straight line proportion to time of flow. On this assumption, when the observations at any intermediate station are referred back to the hour corresponding to the time when the sample collected passed station 292, it is readily possible to calculate the assumed deviation of such sample from the daily average and to correct the observation accordingly. Correction factors for each station as calculated by this method are presented in Table No. 66 below.

TABLE No. 66.—*Correction factors for variation of sewage strength and volume of flow*

Sampling station	Summer: Fluctuation eliminated at station—		Winter: Fluctuation eliminated at station—	
	179	247	179	247
292	1.15	1.15	1.28	1.28
288	1.21	1.20	1.33	1.31
286	1.24	1.22	1.26	1.25
278	1.21	1.18	1.23	1.19
263	1.12	1.06	.84	.92
247	1.34	1.00	----	----
240	.97	1.00	1.12	1.00
227	1.08	1.00	1.01	1.00
196	1.08	1.00	.93	1.00
179	1.00	1.00	1.00	1.00
166	1.00	1.00	1.00	1.00

In the same table are shown correction factors similarly computed on another but similar assumption, namely, that the fluctuations observed at station 292 have terminated at station 247, which represents a time of flow of approximately 27 hours. There are no facts to indicate which of these two assumptions is the closer approximation to the truth.

It may be noted that by application of these correction factors the observations at different stations are affected in different degree, usually to an appreciable extent. For purposes of comparison there are presented in Table No. 67, in parallel columns, the observed quantity units of bacteria growing on agar—(1) uncorrected for this fluctuation in discharge and sewage strength; (2) the same observations corrected on the assumption that the intradiurnal variation has disappeared at station 179; and (3) the observations corrected on the assumption that this variation has been eliminated at station 247. In additional columns these three sets of data are expressed in terms of percentages of the observations of the station at which the bacterial content is a maximum.

Table No. 67.—*Quantity units of bacteria, agar counts, remaining at various sampling stations, observed and corrected values, with corresponding per cents of maximum*

A. SUMMER SEASON

Sampling station	Quantity units			Per cent of station 292 remaining		
	(1)	(2)	(3)	(4)	(5)	(6)
292	28,755,300	33,068,600	33,068,600	100.00	100.00	100.00
288	18,032,500	21,819,300	21,636,000	62.71	65.98	65.43
286	14,637,700	18,150,700	17,858,000	50.90	54.89	54.00
278	12,045,300	14,574,800	14,213,500	41.89	44.07	42.98
263	10,955,800	12,270,500	11,613,100	38.10	37.11	35.12
247	7,032,930	9,424,100	7,032,930	24.46	28.50	21.27
240	4,134,760	4,010,720	4,134,760	14.38	12.13	12.50
227	868,818	938,323	868,818	3.021	2.838	2.627
196	484,737	523,516	484,737	1.686	1.583	1.466
179	194,185	194,185	194,185	.6753	.5872	.5872
166	24,513	24,513	24,513	.08525	.07413	.07413

B. WINTER SEASON

Sampling station	(1)	(2)	(3)	(4)	(5)	(6)
292	963,445	1,233,210	1,233,210			
288	1,288,330	1,713,480	1,167,710			
286	1,271,020	1,601,490	1,568,780			
278	829,930	1,020,820	987,627			
263	[illegible],127,580	1,787,170	1,957,370	100.00	100.00	100.00
240	406,656	455,455	406,656	19.11	25.48	20.78
227	539,915	545,314	539,915	25.37	30.51	27.58
196	99,067	92,132	99,067	4.656	5.155	5.061
179	61,112	61,112	61,112	2.872	3.419	3.122
166	24,769	24,769	24,769	1.164	1.386	1.265

C. SUMMER TRANSITIONAL SEASON

Sampling station	(1)	(2)	(3)	(4)	(5)	(6)
292	12,039,700	13,845,700	13,845,700	100.00	100.00	100.00
288	7,853,250	9,502,430	9,423,900	65.23	68.63	68.06
286	6,446,910	7,994,170	7,865,230	53.55	57.74	56.81
278	2,812,560	3,403,200	3,318,820	23.36	24.58	23.97
263	2,374,860	2,659,840	2,517,350	19.73	19.21	18.18
247	395,137	529,484	395,137	3.282	3.824	2.854
240	553,773	537,160	553,773	4.600	3.880	4.000
227	323,783	349,686	323,783	2.689	2.526	2.339
196	70,492	76,131	70,492	.5855	.5499	.5091
179	27,038	27,038	27,038	.2246	.1953	.1953
166	7,493	7,493	7,493	.0622	.0541	.0541

D. WINTER TRANSITIONAL SEASON

Sampling station	(1)	(2)	(3)	(4)	(5)	(6)
292	2,794,480	3,576,930	3,576,930	100.00	100.00	100.00
288	2,473,480	3,289,730	3,240,200	88.51	91.97	90.59
286	2,353,560	2,965,490	2,941,950	84.22	82.91	82.25
278	1,573,950	1,935,960	1,873,000	56.32	54.12	52.36
263	2,395,620	2,012,320	2,203,970	85.73	56.26	61.62
240	986,775	1,105,190	986,775	35.31	30.90	27.59
227	960,208	969,810	960,208	34.36	27.11	26.84
196	137,485	127,861	137,485	4.920	3.575	3.844
179	74,424	74,424	74,424	2.663	2.081	2.081
166	38,296	38,296	38,296	1.370	1.071	1.071

(1) Quantity units as observed, corrected for tributary inflow and cities only.

(2) Quantity units as in (1), corrected for fluctuation in sewage strength and volume of flow, assumption that intradiurnal variation disappeared at station 179.

(3) Quantity units as in (1), corrected for fluctuation in sewage strength and volume of flow, assumption that intradiurnal variation disappeared at station 247.

(4) Data of (1) expressed in terms of per cent of value at station 292., summer season and station 263, winter season.

(5) Data of (2) expressed in terms of per cent of value at station 292, summer season and station 263, winter season.

(6) Data of (3) expressed in terms of per cent of value at station 292, summer season and station 263, winter season.

A comparison of these corrections indicates that as between the results obtained by the first and the second assumption there is no significant difference. Again comparing the uncorrected figures with those derived by either assumption, the change effected is not very great and generally in one direction, namely, the ratios of counts at downstream stations to those at station 292 become somewhat lower. In other words, the extent and rate of natural purification is somewhat exaggerated by correcting the observed results for intradiurnal fluctuations in volume of flow and sewage strength.

In view of the uncertainty of the assumptions on which these corrections are based and also the immaterial changes on the end results which they produce, it seems preferable, in studying the course and rate of natural purification, to use actual observations, corrected only for tributary flow and not adjusted for fluctuations in discharge and concentration.

RATES OF NATURAL PURIFICATION

The seasonal average quantity units of bacterial pollution observed at each sampling station in the upper river, corrected only as above suggested, are presented in Table No. 68, together with the time of flow in hours from station 292. The percentage which these quantity units at each lower station are of those present at the station of maximum concentration is given, for each of the four seasonal periods, in Table No. 69.

TABLE No. 68.—*Summary of bacteriological observations at all sampling stations, upper Illinois River, corrected for tributary inflow and cities, with times of flow from point of maximum concentration*

[Results in quantity units]

Sampling station	(a) Summer season				(b) Winter season			
	Time of flow, in hours, from station 292	Quantity units observed (corrected for additions by tributaries and cities)			Time of flow, in hours, from station 263	Quantity units observed (corrected for additions by tributaries and cities)		
		Gelatin	Agar	B. coli		Gelatin	Agar	B. coli
292	0.0	28,030,470	28,734,300	499,945		4,889,130	962,445	46,670
285	1.3	18,647,300	18,082,800	376,426		5,627,400	1,288,330	41,680
280	2.0	13,330,100	14,687,700	231,057		5,704,300	1,271,030	30,302
278	5.5	12,421,300	12,045,300	132,132		5,861,470	828,980	26,098
263	14.3	10,511,600	10,956,800	167,908	0.0	11,233,300	2,127,880	46,886
247	27.0	7,318,410	7,082,980	97,007				
240	31.8	4,961,140	4,184,700	77,604	14.4	4,637,840	406,656	26,064
227	41.1	1,160,790	908,818	27,652	25.6	6,357,140	580,915	40,348
196	85.8	574,307	484,737	3,148	71.1	1,621,980	98,067	4,679
179	134.0	212,998	194,185	2,843	120.0	1,288,440	61,[illegible]2	3,578
168	185.0	42,802	24,513	157	160.0	580,317	24,769	1,308

Sampling station	(c) Summer transitional season				(d) Winter transitional season				
	Time of flow, in hours, from station 292	Quantity units observed (corrected for additions by tributaries and cities)			Time of flow, in hours, from station 292	Quantity units observed (corrected for additions by tributaries and cities)			
		Gelatin	Agar	B. coli		Gelatin	Agar	Time of flow, in hours from station 280	B. coli
292	0.0	26,308,200	12,089,700	303,652	0.0	9,097,100	2,794,480		88,140
285	1.3	16,228,600	7,853,250	238,741	1.3	8,802,300	2,473,480		89,077
280	2.0	12,875,800	6,446,910	272,122	2.0	8,402,300	2,353,560	0.0	89,737
278	5.5	7,979,430	2,812,560	100,442	5.4	8,314,040	1,573,980	2.4	42,680
263	14.2	4,517,170	2,374,860	107,706	13.4	8,522,350	2,395,620	11.4	77,007
247		972,205	396,137	12,904					
240	30.0	1,048,690	553,773	18,638	25.9	4,686,870	996,775	22.9	33,441
227	39.2	645,152	333,783	8,032	32.7	3,956,240	980,205	31.7	28,781
196	86.0	140,078	70,492	674	77.0	738,426	137,495	75.0	3,039
179	140.0	82,604	27,038	384	122.0	495,422	74,424	120.0	2,934
168	184.0	16,479	7,408	137	160.0	241,813	38,206	146.0	678

TABLE No. 69.—*Bacteria remaining at various sampling stations, upper Illinois River, corrected for tributary inflow and cities, expressed in percentages of the maximum and with times of flow below this maximum*

Sampling station	(*a*) Summer season				(*b*) Winter season			
	Time of flow, in hours, from station 292	Per cent of maximum remaining (corrected for additions by tributaries and cities)			Time of flow, in hours, from station 263	Per cent of maximum remaining (corrected for additions by tributaries and cities)		
		Gelatin	Agar	B. coli		Gelatin	Agar	B. coli
292	0.0	100.00	100.00	100.00				
288	1.3	66.87	62.71	76.66				
286	2.0	47.56	50.90	47.16				
278	5.5	44.35	41.90	26.97				
263	14.3	37.88	38.10	28.35	0.0	100.00	100.00	100.00
247	27.0	28.13	24.46	19.80				
240	31.8	17.80	14.35	15.84	14.4	41.30	19.11	• 55.64
227	41.1	4.144	3.021	5.644	25.6	36.50	25.37	95.85
196	85.8	2.090	1.686	.0426	71.1	14.41	4.656	8.981
179	134.0	.7040	.6758	.5002	129.0	11.45	2.872	5.389
166	185.0	.1884	.09825	.08304	168.0	4.991	1.104	2.724

Sampling station	(*c*) Summer transitional season				(*d*) Winter transitional season			
	Time of flow, in hours, from station 292	Per cent of maximum remaining (corrected for additions by tributaries and cities)			Time of flow, in hours, from station 292	Per cent of maximum remaining (corrected for additions by tributaries and cities)		
		Gelatin	Agar	B. coli		Gelatin	Agar	Time of flow, in hours, from station 286	B. coli
292	0.0	100.00	100.00	100.00	0.0	100.00	100.00		
288	1.3	61.93	65.23	78.62	1.3	96.76	88.51		
286	2.0	48.14	52.55	69.62	2.0	93.02	84.72	0.0	100.0
278	5.5	30.53	23.36	33.08	5.4	91.29	86.22	3.4	67.47
263	14.2	17.24	19.73	35.47	12.4	93.06	85.73	11.4	88.81
247		3.710	3.282	4.217					
240	30.0	4.002	4.600	6.126	25.9	51.54	35.31	23.9	37.29
227	39.2	2.462	2.699	2.646	33.7	43.46	34.36	31.7	32.07
196	86.0	.5575	.5835	.2220	77.0	8.117	4.926	75.0	4.044
179	140.0	.2008	.2366	.1265	122.0	5.446	2.085	120.0	3.286
166	194.0	.08289	.0632	.04512	160.0	2.686	1.370	156.0	.7586

It may be observed that the rates of change defined by gelatin counts and by *B. coli* on samples collected at successive downstream points correspond quite generally with similar observations of agar counts. Therefore, for a study of the rates of natural purification, the agar results may be taken as representative of these changes.

Taking first the observations of agar counts during the summer season, if the data of Table No. 69 are plotted on semilogarithmic cross-section paper, with the percentages of bacteria remaining at successive stations as ordinates and the time of flow as abscissæ, the change occurring from station to station is graphically defined. (Fig. 21.) An inspection of this chart shows that a very sharp decrease in bacteria—about 50 per cent—takes place in the first two hours from station 292 to 286.

This is a turbulent river stretch in which the physical and biological environment of bacteria from the drainage canal undergoes a sharp change. From station 236 to 247 there is a distinct slowing up of the rate of decrease and then an acceleration to station 240, which becomes even more marked until station 227 is reached. From this latter station the rate is again markedly reduced to station 166 and apparently tends to become somewhat more uniform. The time interval through Peoria Lake being an estimate rather than a calculation, and possibly longer than recorded, the rate defined in this lower section must be considered as approximate only.

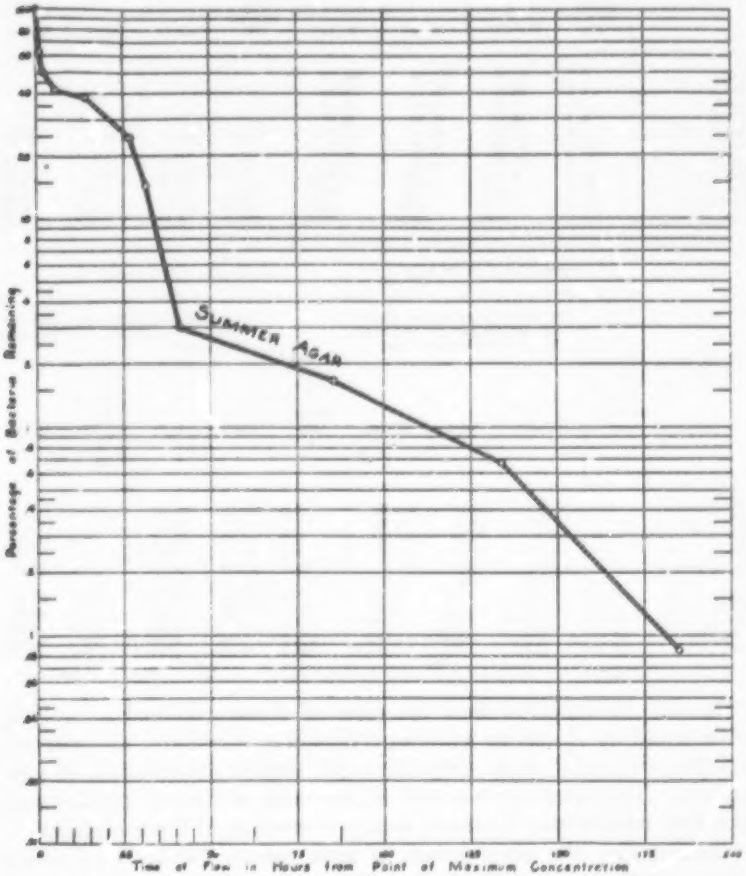


FIG. 21.—Rate of decrease in agar counts, upper Illinois River, summer season

From a general inspection of these observations as a whole, the conclusion would seem to be that bacterial purification in this part of the river during the summer months proceeds at distinctly different rates in different sections and does not consistently follow the law found to obtain in the Ohio River between Cincinnati and Louisville, namely, that the rate of purification progressively diminished in passing downstream. However, when more broadly viewed, this same general slowing up of the rate of purification is apparent. For instance, the rate of decrease from station 292 to 263, from this latter point to 196, and thence to station 166 is in fact a decrease at diminishing rates. How far the intermediate departures from the general trend indicated by observations at these points may be due to real differences in the trend of bacterial death rates and how far they may be due to observation errors, such as the effect of inflow not properly corrected, the effect of intradiurnal fluctuations in discharge and concentration, the result of unrepresentative sampling, etc., it is impossible to say. However, since we are unable to point specifically to factors of error which might reasonably be expected to distort a rate of purification as described by a smooth curve to that indicated by the observations, it does not seem justifiable to ascribe the apparent alternating changes in successive river sections to observation errors.

Turning now to the rates of purification in winter as defined by the observed agar counts, it will be at once noted that no decrease but rather an increase in bacteria was observed below station 292 until the maximum was reached at station 263. Therefore any attempt to derive a rate of bacterial purification during the winter must employ this point of maximum pollution at station 263 as the starting point or base. Accordingly the per cents of bacteria remaining are computed in this manner. Plotting these observed percentages at succeeding stations below station 263 against times of flow, as was done for the summer season, a somewhat different array of points is obtained.

The rate is quite rapid to station 240, and then apparently increases slightly to station 227, from which point a fairly uniform rate of decrease may be discerned. As compared with the summer observations, the initial decrease from the maximum is not so precipitous, and the rate between lower stations is likewise less rapid. On the whole, except for the reversal between stations 240 and 227, the winter observations define a somewhat more regular path than do similar results for the summer season.

Passing now to the transition seasonal periods, averages of observations for May and October, during which time biological conditions are in a state of adjustment toward or away from those obtaining in the warm summer period, are plotted as before in Figure 23.

Here, as in the summer observations, a rapid decline in bacteria takes place in the turbulent upper section from station 292 to 278

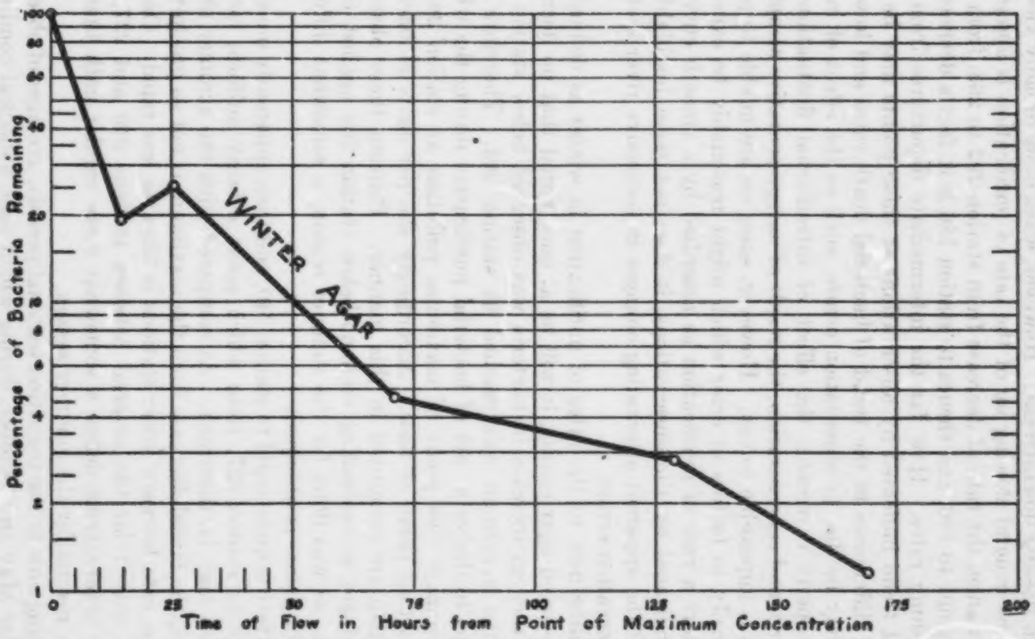


FIG. 22.—Rate of decrease in agar counts, upper Illinois River, winter season

and becomes less marked at successive stations. Except for an apparent reversal between stations 247 and 240, the change is quite orderly throughout, much more so indeed than is indicated by the observations for the summer months. Since the average data for station 247 during this seasonal period is derived from observations for only 17 days in May and none in October, it is entirely possible that the observed average obtained is not thoroughly representative of conditions at this station throughout the period under consideration and should therefore be given comparatively less weight.

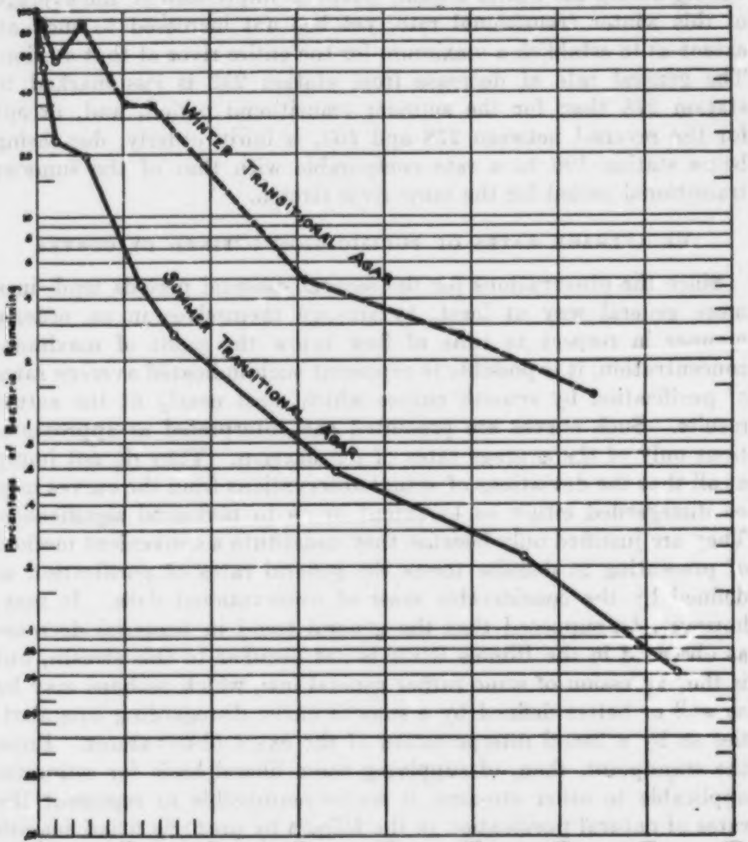


FIG. 23.—Rates of decrease in agar counts, upper Illinois River. Winter transitional and summer transitional seasons

The winter transitional period, composed of observations during the months of April and November (plotted in fig. 23), when biological changes were in a state of adjustment toward or departing from those prevailing in the cold winter months, shows still different rates of natural purification. During one of the months of this period, April, an exceptionally severe flood occurred throughout the river channel. Even with this disturbing influence and with few exceptions, a reasonably definite rate of purification is defined by the observations. The maximum concentration at station 263, prevailing during the winter season, leaves its impression on the average of this winter transitional rate, yet has not increased to such an extent as to establish a maximum for the entire river at that station. The general rate of decrease from station 292 is less marked to station 278 than for the summer transitional period, and, except for the reversal between 278 and 263, is fairly orderly, decreasing below station 196 to a rate comparable with that of the summer transitional period for the same river stretch.

THE AVERAGE RATES OF PURIFICATION DEFINED BY CURVES

Since the observations for the several seasonal periods tend, in a more general way at least, to arrange themselves in an orderly manner in respect to time of flow below the point of maximum concentration, it is possible to represent such indicated average rates of purification by smooth curves which most nearly fit the actual results. Such curves are presented and interpreted as approximations only of the average rates of purification. They do not imply at all that the deviations of actual observations from the curves may be disregarded either as to extent or as to biological significance. They are justified only because they constitute a convenient method of presenting in definite terms the general rates of purification as defined by the considerable mass of observational data. It may, however, be supposed that the general trend in bacterial decrease as observed in the Illinois River is not peculiar to this stream, but is the expression of some rather general law, which perhaps may be as well or better defined by a smooth curve disregarding irregularities as by a literal interpretation of the exact observations. From the standpoint, then, of supplying some liberal basis for estimates applicable to other streams, it seems permissible to represent the rates of natural purification in the Illinois by properly fitted smooth curves, which admittedly smooth out and idealize the actual observations. Since certain distortions of the data are inevitable by such a process, a formulation of such curves as are derived seems scarcely justified. Accordingly, curves defining the various rates of purification in bacterial content for the four seasons, drawn by the simple process of inspection, are presented in the following figures, Nos. 24 to 29, inclusive.

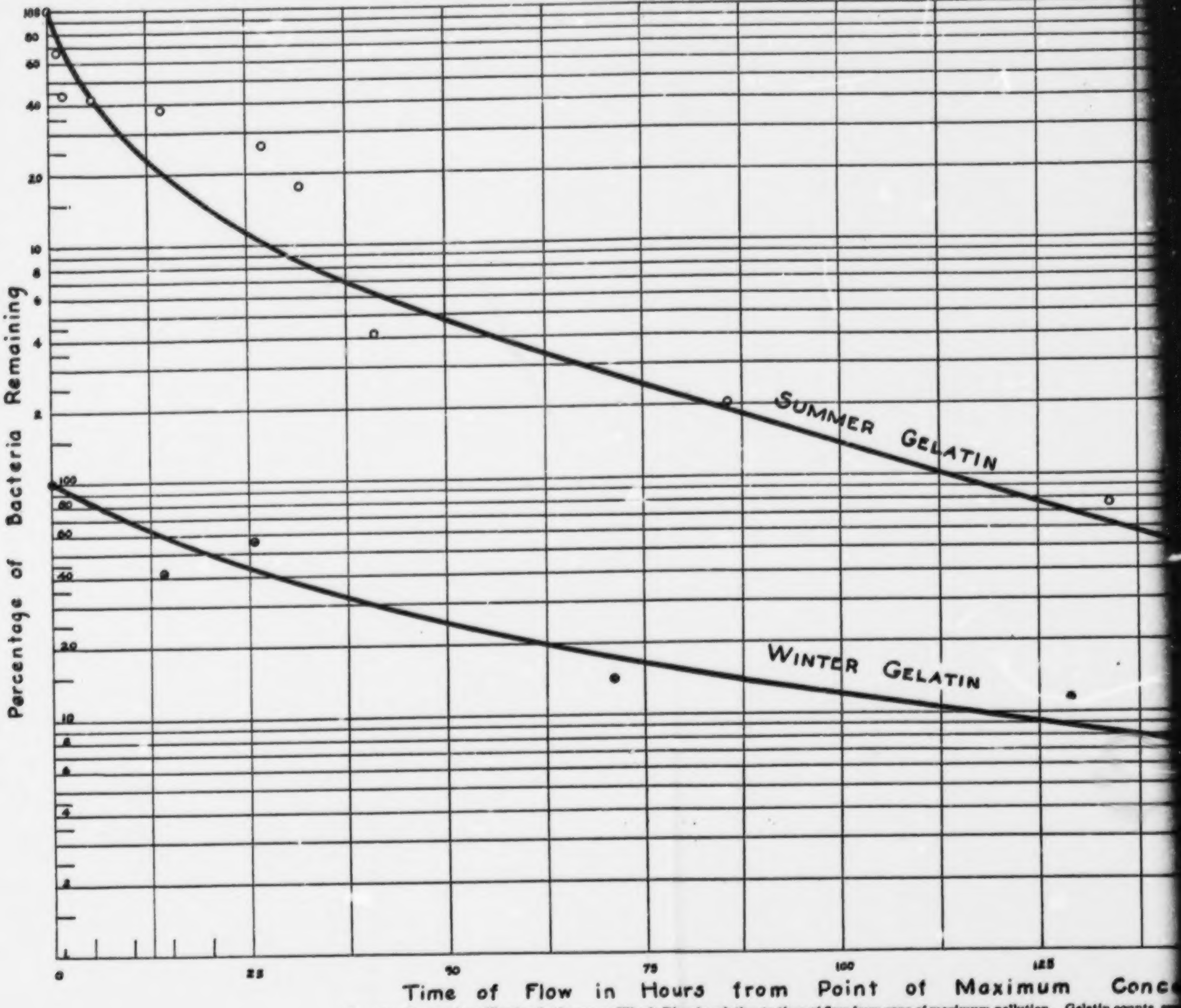
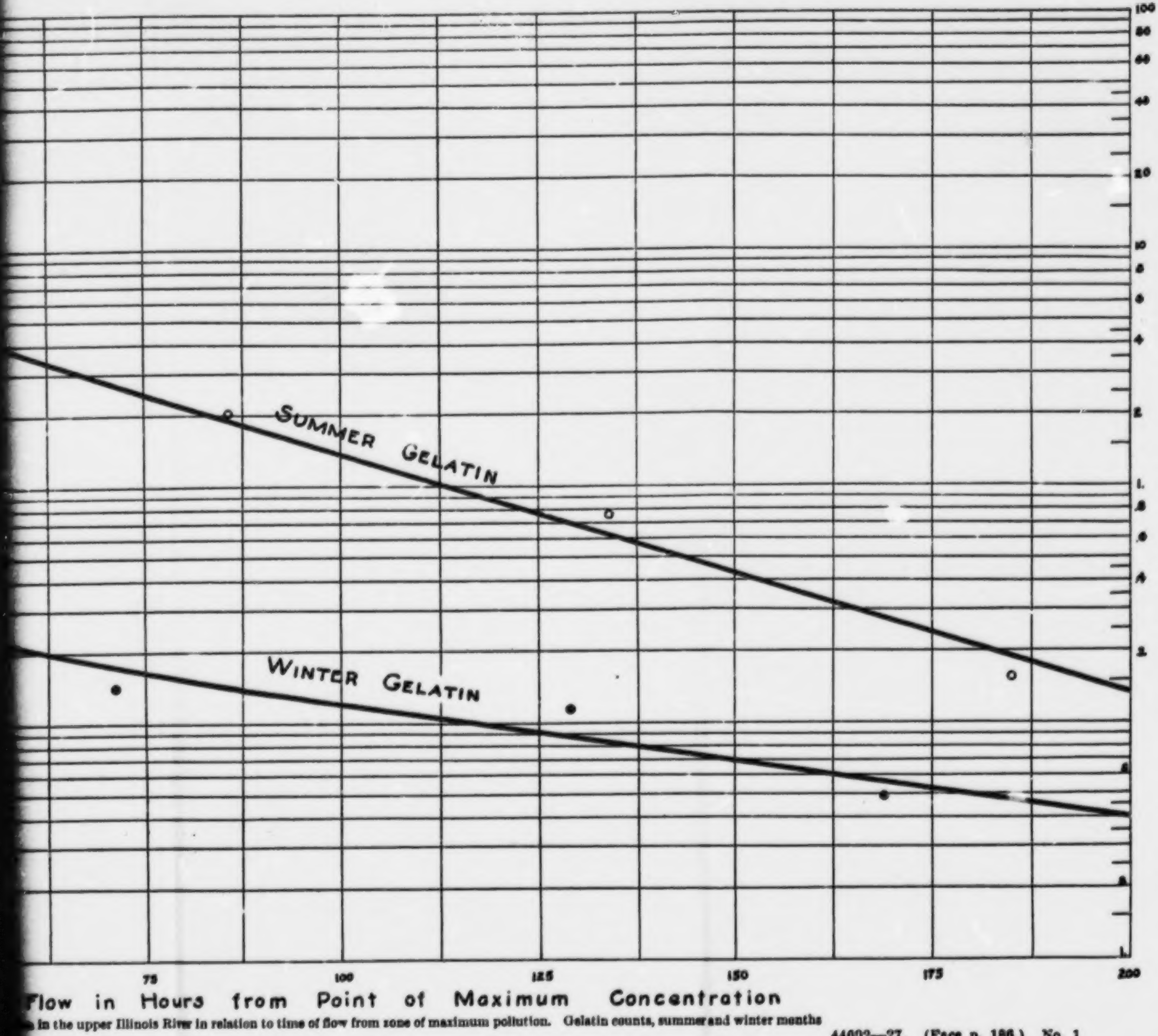


FIG. 24.--Bacterial purification in the upper Illinois River in relation to time of flow from zone of maximum pollution. Gelatin counts,



in the upper Illinois River in relation to time of flow from zone of maximum pollution. Gelatin counts, summer and winter months

44602—27. (Face p. 186.) No. 1

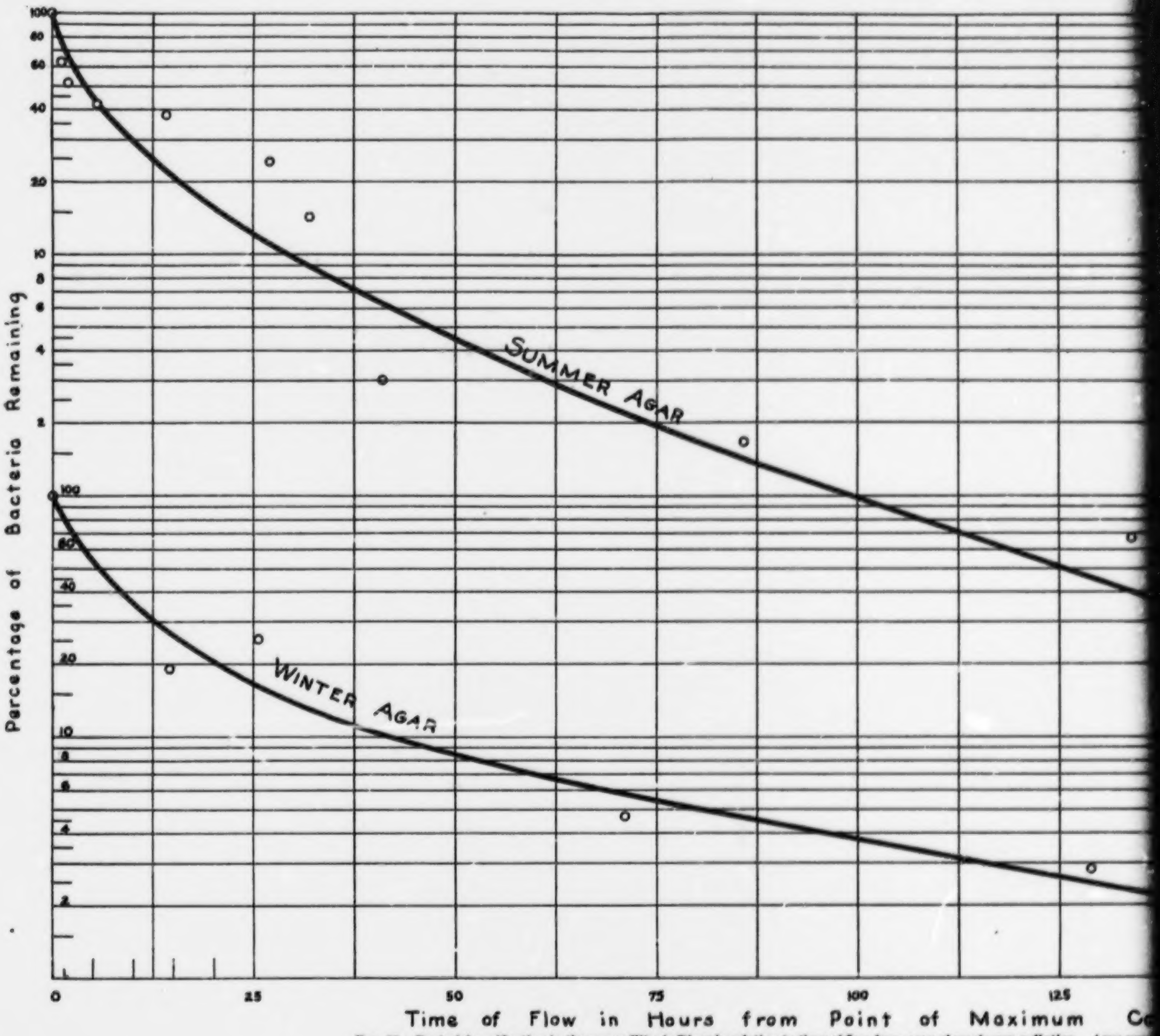
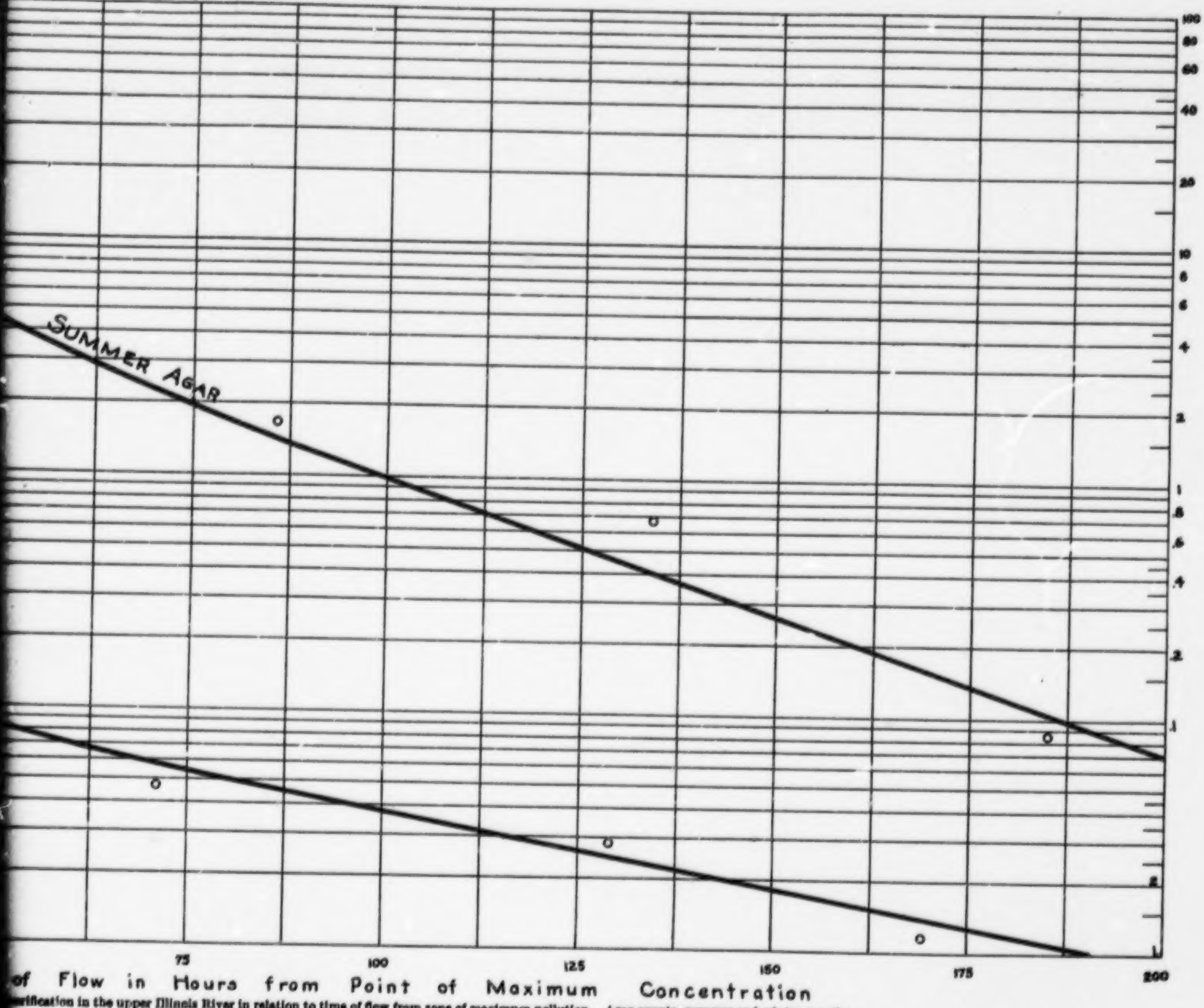


FIG. 25.—Bacterial purification in the upper Illinois River in relation to time of flow from zone of maximum pollution. Agar

86b



rification in the upper Illinois River in relation to time of flow from zone of maximum pollution. Agar counts, summer and winter months

44602—27. (Face p. 186.) No. 2

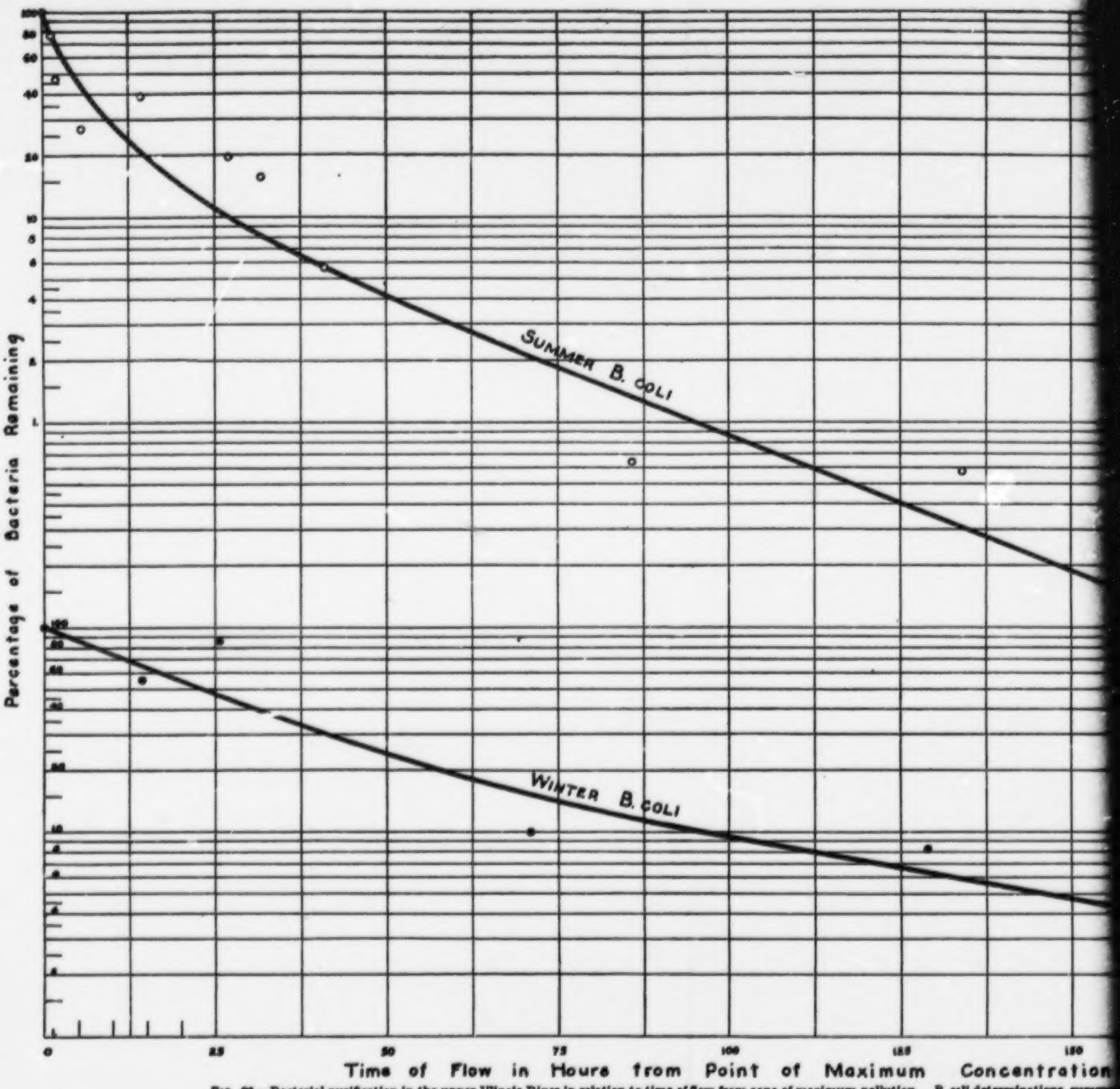
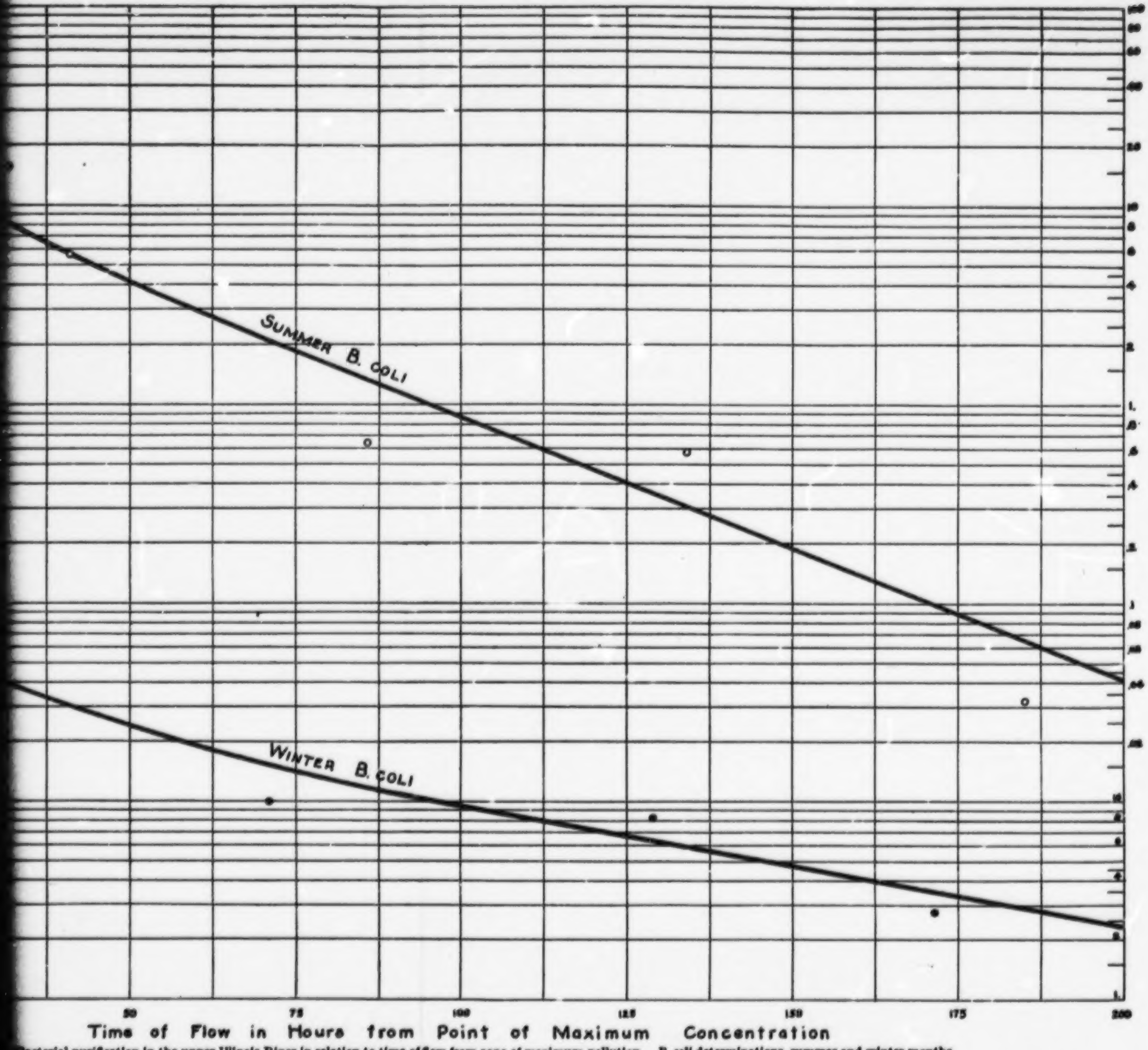


FIG. 26.—Bacterial purification in the upper Illinois River in relation to time of flow from zone of maximum pollution. *B. coli* determinations, summ

186c



Bacterial purification in the upper Illinois River in relation to time of flow from zone of maximum pollution. *B. coli* determinations, summer and winter months

44602—27. (Face p. 186.) No. 3

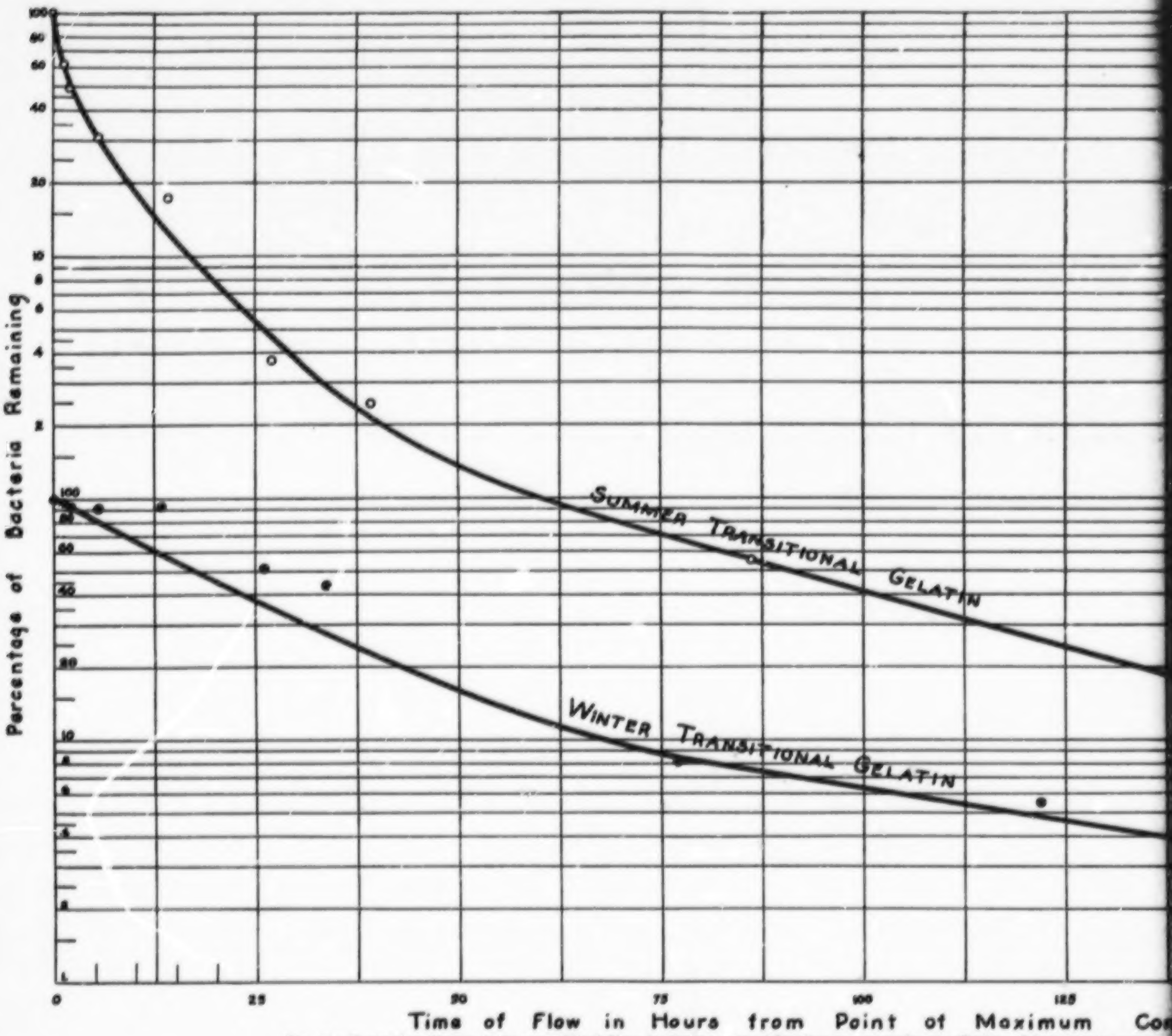
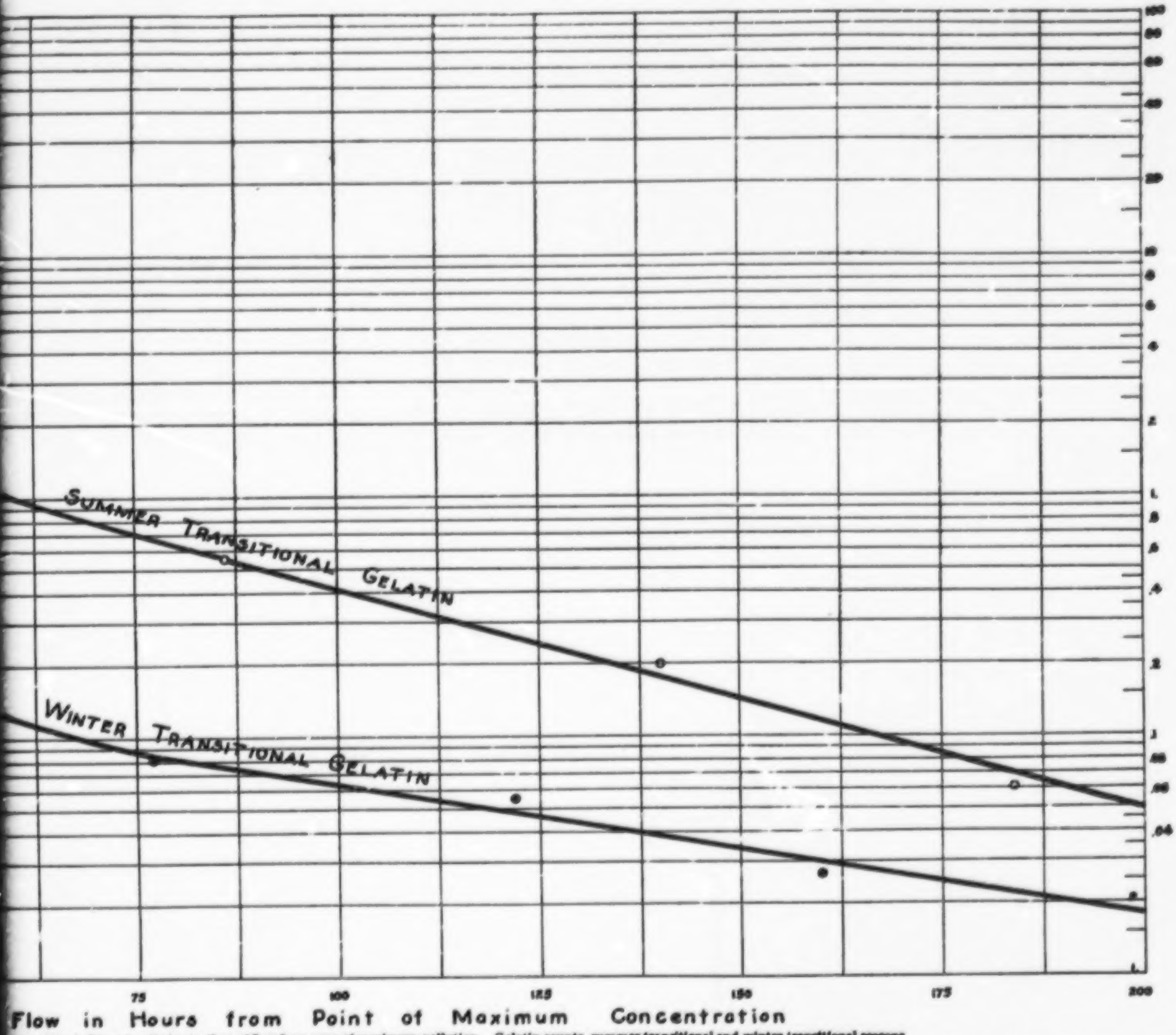


FIG. 27.—Bacterial purification in the upper Illinois River in relation to time of flow from zone of maximum pollution. Gelatin counts, summer

186d



pper Illinois River in relaticn to time of flow from zone of maximum pollution. Gelatin counts, summer transitional and winter transitional seasons

44602—27. (Face p. 186.) No. 4

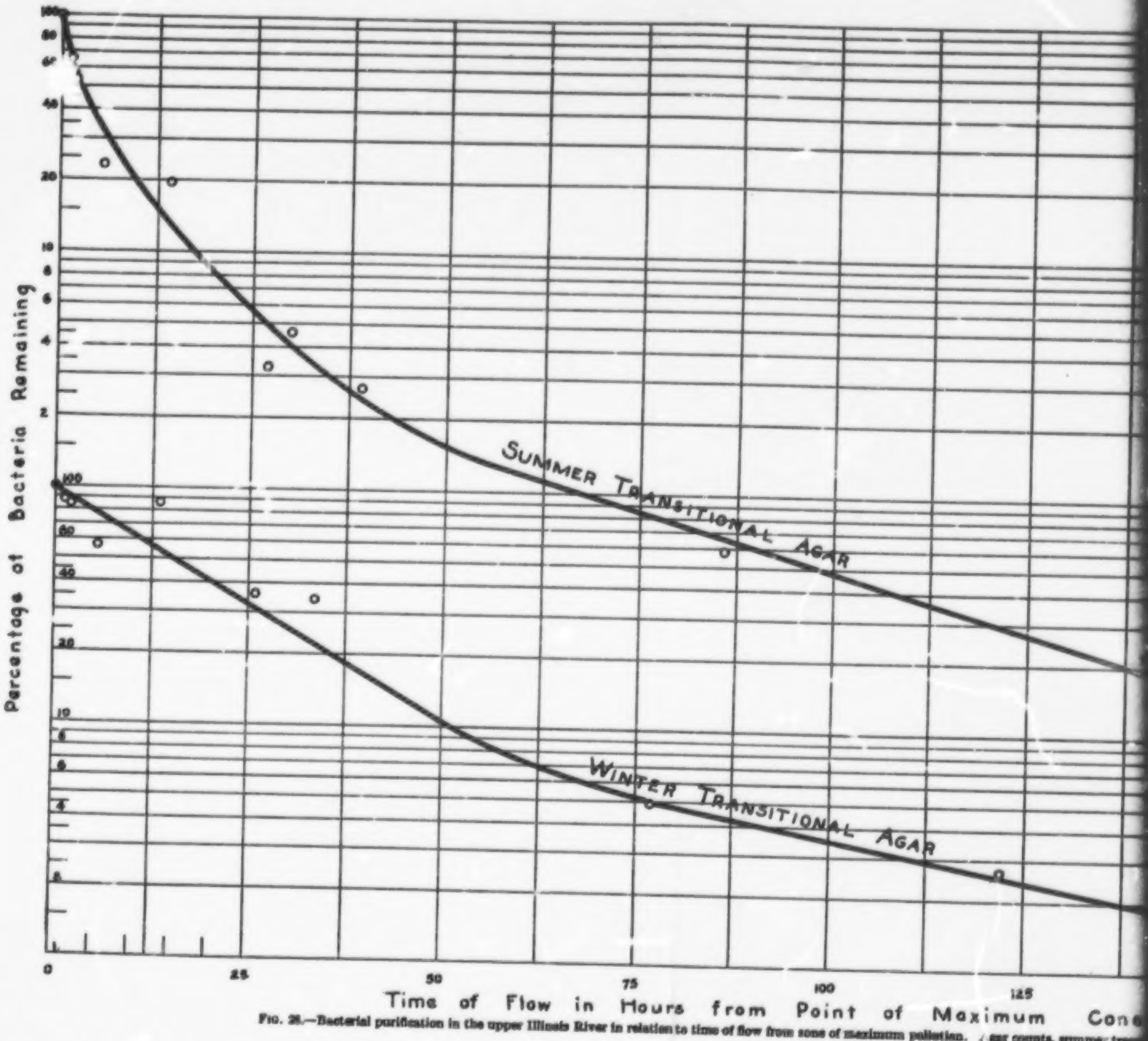
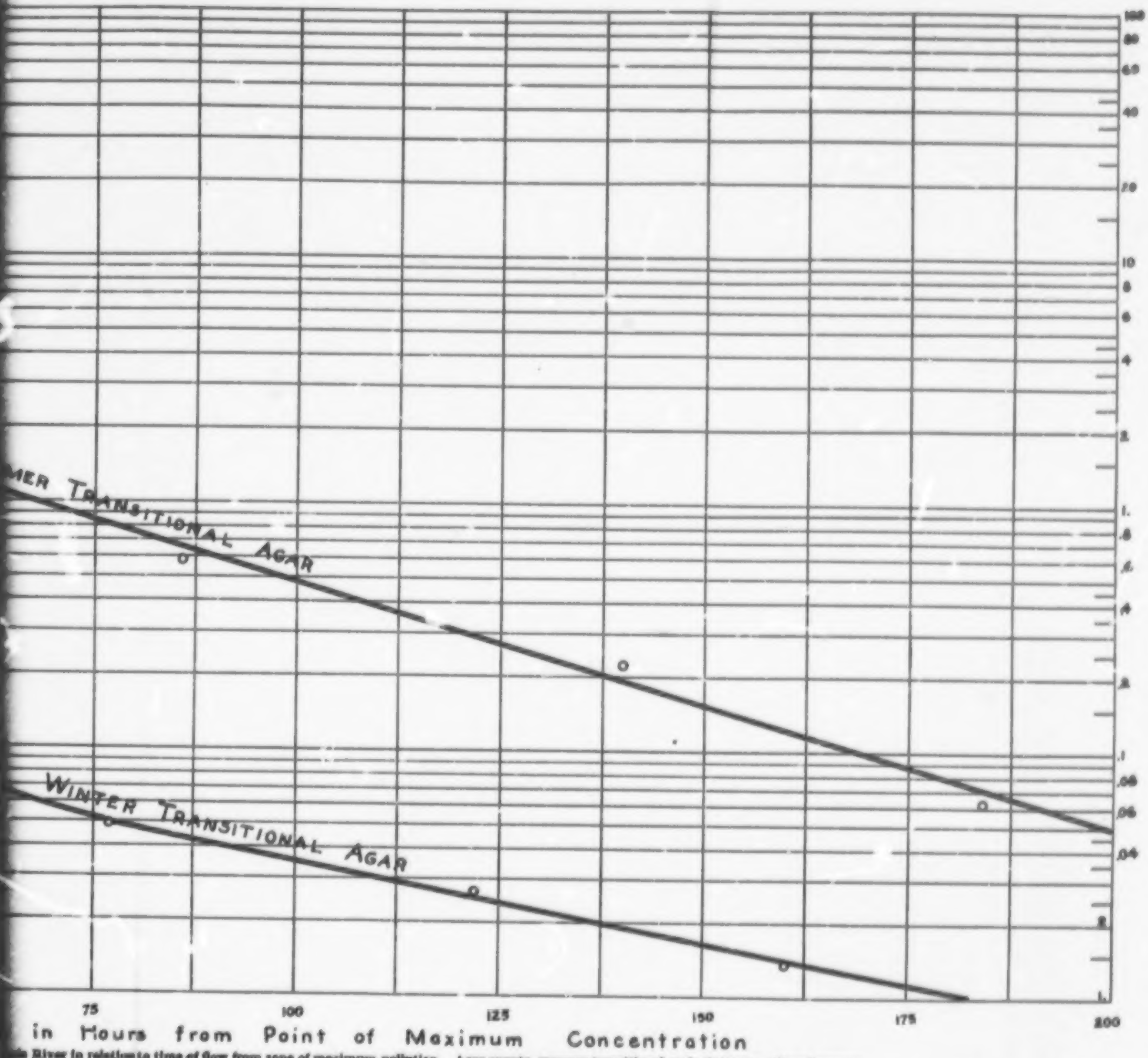


FIG. 28.—Bacterial purification in the upper Illinois River in relation to time of flow from zone of maximum pollution. Agar counts, summer tra



River in relation to time of flow from zone of maximum pollution. Agar counts, summer transitional and winter transitional seasons

44602—27. (Face p. 186.) No. 5

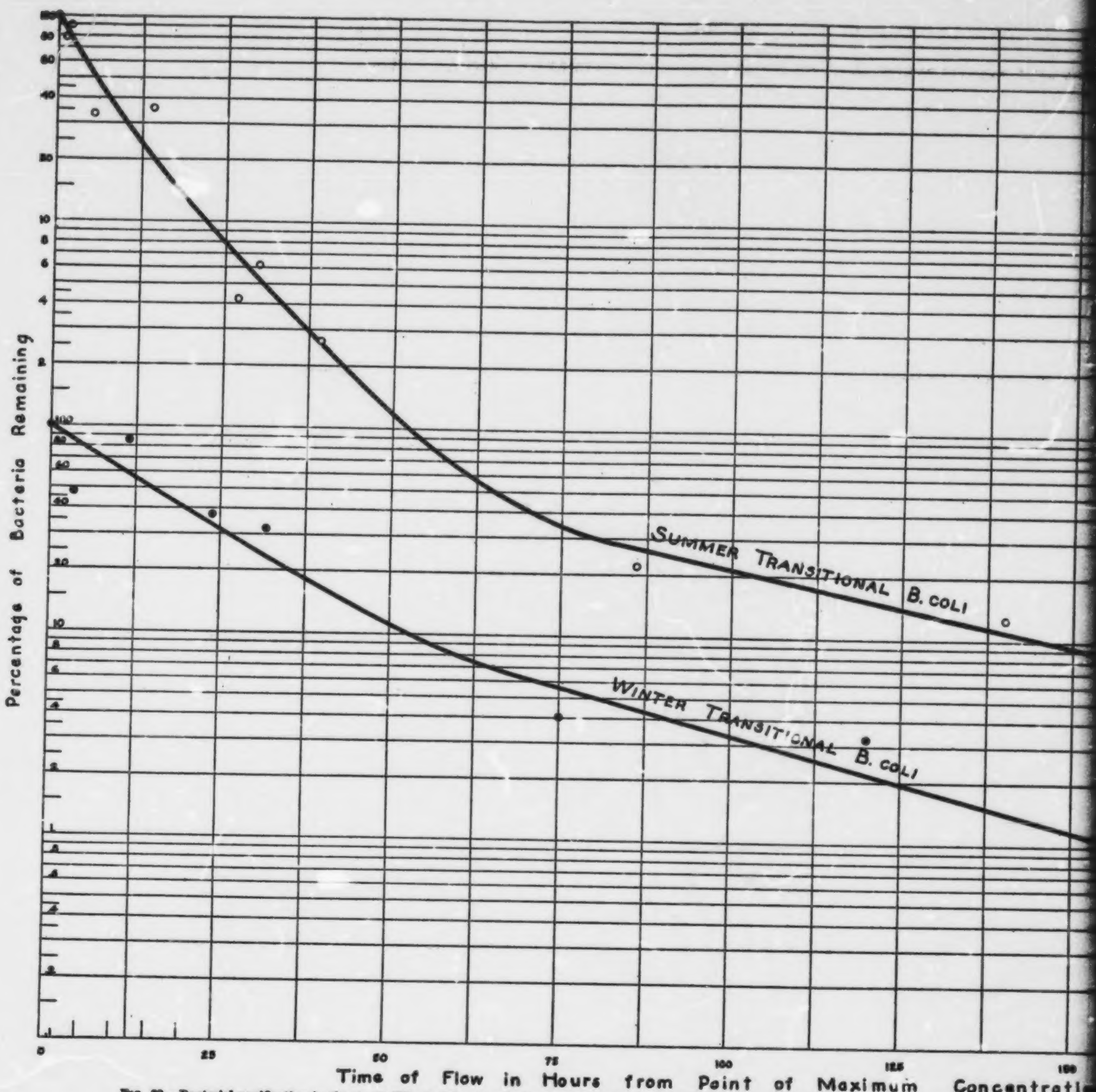
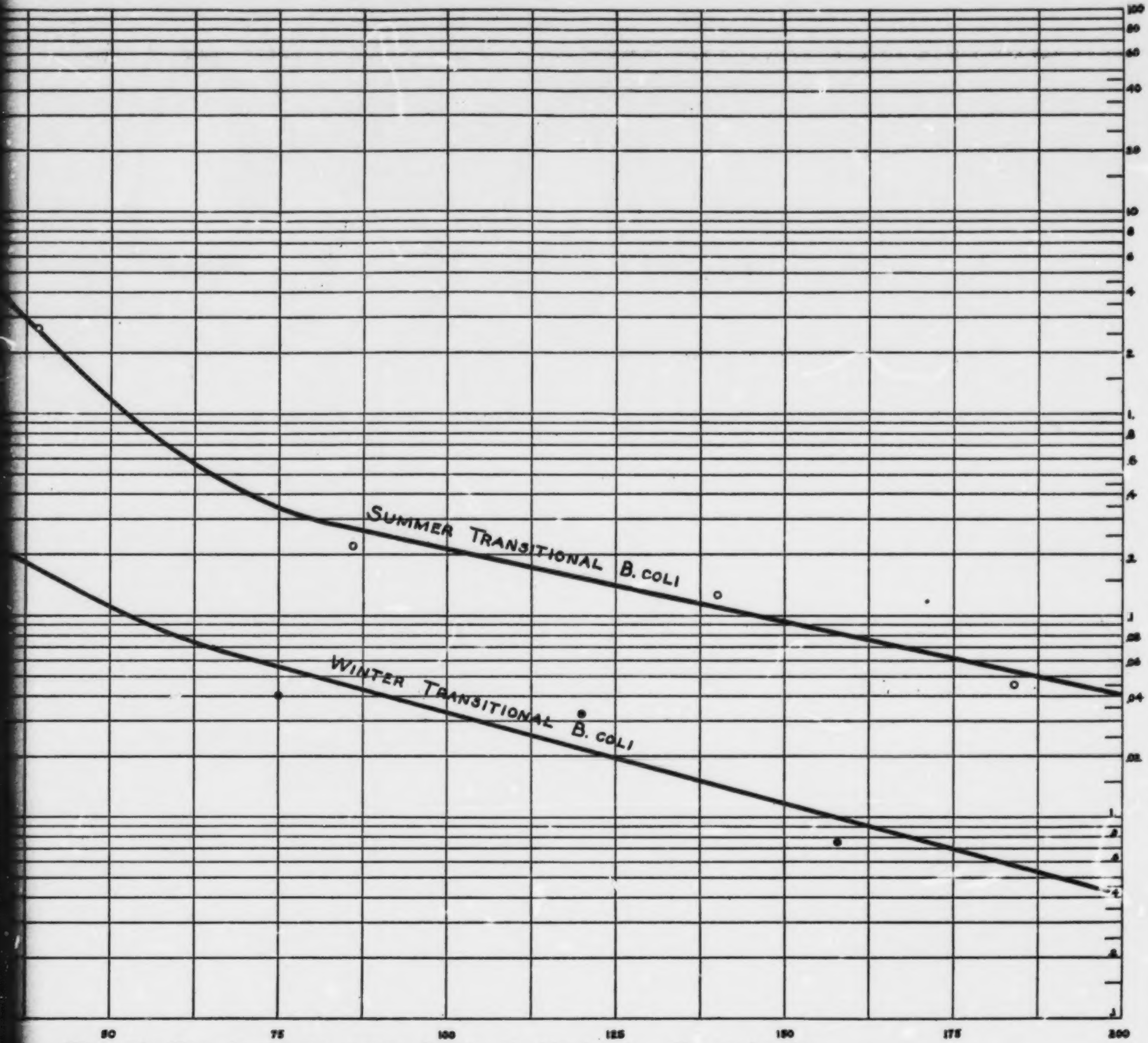


FIG. 29.—Bacterial purification in the upper Illinois River in relation to time of flow from zone of maximum pollution. *B. coli* determinations, summer tran



in the upper Illinois River in relation to time of flow from zone of maximum pollution. *B. coli* determinations, summer transitional and winter transitional seasons

44602—27. (Face p. 186.) No. 6

From the general curves derived as above described ordinates have been tabulated representing the approximate mean percentages of bacteria remaining at stated intervals in the several seasonal periods. These general rates of natural purification are presented in Table No. 70.

TABLE No. 70.—*Coordinates of curves describing decrease in gelatin counts, agar counts, and B. coli, in relation to time of flow from zone of maximum pollution, upper Illinois River*

Time of flow from maximum in hours	Summer season			Winter season		
	Percentage of bacteria remaining			Percentage of bacteria remaining		
	Gelatin count (maximum per cubic centimeter=3,310,000)	Agar count (maximum per cubic centimeter=3,420,000)	B. coli (maximum per cubic centimeter=37,100)	Gelatin count (maximum per cubic centimeter=751,000)	Agar count (maximum per cubic centimeter=142,000)	B. coli (maximum per cubic centimeter=3,030)
0	100	100	100	100	100	100
5	44.8	46.0	46.5	80.0	54.5	86.0
10	27.5	29.5	28.6	65.2	36.3	74.5
20	14.3	15.8	14.3	48.5	20.7	55.5
30	9.00	9.80	8.70	37.6	14.0	41.5
40	6.38	6.50	5.86	30.0	10.6	31.0
50	4.70	4.50	4.10	23.9	8.45	22.1
60	3.59	3.21	2.95	19.8	7.00	18.1
70	2.79	2.30	2.15	17.0	5.90	15.0
80	2.19	1.70	1.56	15.1	5.03	12.7
90	1.72	1.29	1.17	13.6	4.35	10.9
100	1.37	.990	.861	12.1	3.78	9.40
125	.765	.505	.405	9.10	2.62	6.65
150	.425	.262	.188	6.90	1.82	4.70
175	.239	.136	.087	5.22	1.37	3.30
200	.135	.071	.041	......	......	......

Time of flow from maximum, in hours	Percentage of bacteria remaining					
	Summer transitional period			Winter transitional period		
	Gelatin count (maximum per cubic centimeter =3,070,000)	Agar count (maximum per cubic centimeter =1,430,000)	B. coli (maximum per cubic centimeter =35,500)	Gelatin count (maximum per cubic centimeter =1,080,000)	Agar count (maximum per cubic centimeter =226,000)	B. coli (maximum per cubic centimeter =9,120)
0	100	100	100	100	100	100
5	33.0	34.5	52.5	82.0	79.5	79.0
10	18.4	19.3	30.4	67.0	62.5	62.0
20	7.85	8.90	12.0	45.2	40.5	39.5
30	4.45	4.05	5.25	31.3	26.0	25.[illegible]
40	2.06	2.33	2.40	22.2	16.6	16.3
50	1.33	1.55	1.16	15.9	10.5	11.0
60	.990	1.20	.635	12.0	7.40	7.90
70	.785	.955	.407	9.50	5.80	6.20
80	.625	.760	.300	8.10	4.78	5.03
90	.519	.605	.252	7.15	4.05	4.20
100	.418	.462	.218	6.35	3.50	3.23
125	.280	.273	.140	4.63	2.41	1.97
150	.145	.153	.0925	3.38	1.68	1.16
175	.0860	.0875	.0607	2.43	1.12	.60
200	.051	.0495	.0400	1.78	......	......

Except for all determinations in the winter period and the *B. coli* of the winter transitional season, these ordinates are referred to observations at station 292 and indicate with fair precision the concentration of bacteria that might be expected to obtain at successive points on the river. Although they do not correspond closely with observations at our sampling stations, they do nevertheless distinguish as between different ranges of pollution, for example between zones where pollution ranges over 1,000,000, from 100,000 to 500,000, from 10,000 to 50,000, etc., bacteria per cubic centimeter. It is probable too that estimates for almost any point on the river made by application of these curves would be about as reliable as data derived from a comparatively small number of direct observations of bacterial numbers.

Concerning the increase in bacterial content between stations 292 and 263 during the winter months, it is observed that a similar condition was noted on the Ohio River, where the actual bacterial content tended to increase to a point which corresponded in summer to about 15 hours flow from the sewer outlets. In winter this point was somewhat farther downstream. The sampling errors which might account for this apparent increase in the Ohio River below Cincinnati do not seem competent to account for the increase observed in winter in the Illinois River, since it is not apparent that, as between stations 292 and 263, the sampling errors should be of different trend or of very different extent in summer than in winter. On the other hand, there is some indication that throughout the year the bacteria present in the drainage canal tend to a primary increase in numbers up to a certain maximum, which in the summer is reached somewhere between Summit and Lockport and in winter lower downstream at about station 263. Comparison of observations at Summit with those at Lockport are not entirely convincing evidence of a bacterial increase, however, because of the sewage and industrial wastes which are added to the canal between these two places. Nevertheless, when there is taken into consideration the observations on the Ohio River, the rather consistent increase in counts between Summit and Lockport and the extension of this maximum zone to well below Lockport in winter, it seems reasonable to infer that when sewage is discharged into a diluting watercourse there is a general tendency to an increase in bacterial numbers during a certain period which is longer in winter than in summer. As pointed out in the Ohio River studies,[4] this does not necessarily imply cell multiplication; it may be merely the result of disintegration of clumps. In view of all the observations of both streams, even though none of them taken singly is convincing, it seems quite improbable that they should all be in error.

---

[4] Public Health Bulletin No. 143, p. 272.

LOWER ILLINOIS RIVER

The lower Illinois River, extending from Peoria to the mouth, drains mostly a flat agricultural country, the run-off from which during the summer months is quite low, but during times of heavy rainfall contributes appreciable amounts of soil pollution. The larger tributaries are the Mackinaw, Spoon, Sangamon, Crooked Creek, and Macoupin, with a combined average flow of 2,915 second-feet in summer. The discharge of the Illinois increased from 11,660 second-feet at station 166 to 16,090 second-feet below the mouth of the Macoupin during this period, so that the run-off from the important tributaries which were under observation constituted over 65 per cent of the total added volume. During the winter months, owing to the closing of one branch laboratory, observations were not continued on the Sangamon and Crooked Creek; the total inflow contributed to the lower Illinois during this season averaged 10,300 second-feet, of which 3,740 second-feet, or 36 per cent, came from the Mackinaw, Spoon, and Macoupin, on which observations were maintained.

During the summer season, the density of bacterial content of the tributaries is generally less than that of the main stream, except for the Macoupin, as judged by bacteria growing on gelatin. However, during the winter the conditions are reversed and all the tributaries observed carried higher concentrations of bacteria than were present in the Illinois above the junctions, so that, during this period at least, the tributaries were increasing the bacterial pollution instead of diluting it.

The cities of Peoria and Pekin, with a total estimated equivalent sewered population of over 656,000, effect a rise in bacterial concentration in the river as shown by the following comparative summary of observations at station 166 above Peoria and at station 148 below Pekin:

	Summer (bacteria per cubic centimeter)			Winter (bateria per cubic centimeter)		
	Gelatin	Agar	B. coli	Gelatin	Agar	B. coli
Station 166	4,830	2,870	16	30,700	1,420	70
Station 148	281,000	254,000	3,730	29,000	9,440	180
Increase	276,000	251,000	3,710	....	8,020	110

Additional pollution contributed by the sewered populations of places below Pekin is small in amount and exerts no appreciable effect on the river.

A second stretch of river is therefore available for a study of the rates of natural purification occurring. While the maximum densities of pollution are not nearly so intense as those existing in the upper river, yet they are sufficiently great to make possible the observation of appreciable changes at successive sampling stations downstream. As in the treatment of the upper river data, it is first necessary to apply corrections to the observations for the effect of tributary inflow. This has been done in exactly the same was as before explained. Such a series of factors to be applied to the actual observations is given in Table No. 71.

By applying these factors to the corresponding seasonal average observations expressed in quantity units, there is obtained for each season and for each sampling station the quantity units of bacteria remaining of those found at the point of maximum concentration. These corrected observations, together with the times of flow from station 148 to successive downstream sampling points, are arranged in Table No. 72. The same data, expressed in terms of percentages of the maximum occurring at station 148, are given in Table No. 73 and define the rates at which bacteria were observed to decrease in the lower river during the various seasonal periods.

TABLE No. 71.—*Correction factors for observed quantity units of bacteria added by tributaries and cities*

Sampling station	Gelatin	Agar	B. coli	Gelatin	Agar	B. coli
	(a) Summer season			(b) Winter season		
148	1	1	1	1	1	1
122	.996287	.997075	.998098	.922458	.945064	.959604
101	.965645	.969385	.976286			
89	.936528	.910196	.862738			
84	.904265	.822083	.623781			
78	.733796	.744550	.108555			
77	.733796	.744550	.108555			
43	.733796	.744550	.108555	.728009	.736036	.870634
32	.733796	.744550	.108555			
31	.733796	.744550	.108555	.728009	.736036	.870634
26	.733796	.744550	.108555	.728009	.736036	.870634
	(c) Summer transitional season			(d) Winter transitional season		
148	1	1	1	1	1	1
122	.977069	.991422	.983323	.910518	.952140	.939843
101	.870915	.906895	.915217	.693523	.651591	.703578
89	.836401	.847867	.845361	.614658	.574537	.699778
84						
78						
77	.672871	.739484	.578657	.555538	.545640	.635755
43	.672871	.739484	.578657	.555538	.545640	.635755
32						
31	.672871	.739484	.578657	.555538	.545640	.635755
26	.672871	.739484	.578657	.555538	.545640	.635755

TABLE NO. 72.—*Summary of bacteriological observations at all sampling stations, lower Illinois River, corrected for tributary inflow and cities, with times of flow from point of maximum concentration*

[Results in quantity units]

Sampling station	Time of flow in hours from station 148	Quantity units observed (corrected for additions by tributaries and cities)			Time of flow in hours from station 148	Quantity units observed (corrected for additions by tributaries and cities)		
		Gelatin	Agar	B. coli		Gelatin	Agar	B. coli
	(a) Summer season				(b) Winter season			
148	0	3,177,380	2,981,120	41,990	0	597,870	187,718	3,682
122	23.0	761,609	676,104	7,237	17.7	412,816	75,511	1,841
101	45.1	289,356	366,844	1,476				
89	56.0	289,703	337,771	1,488				
84	62.1	191,709	219,446	37				
78	68.5	340,951	354,056	40				
77	67.7	189,821	196,898	180				
43	93.4	168,930	125,090	158	72.2	464,638	59,272	457
33	106.8	129,933	63,704	157				
31	102.3	106,364	70,514	87	80.1	464,352	58,513	459
26	107.9	125,314	93,276	94	84.5	489,297	68,915	376
	(c) Summer transitional season				(d) Winter transitional season			
148	0	910,665	643,065	6,486	0	498,390	214,740	3,976
122	18.4	293,528	214,762	2,775	16.8	273,761	109,048	1,188
101	40.2	158,646	103,204	1,528	38.9	78,976	57,111	1,297
89	50.2	200,906	124,187	919	49.0	83,698	49,830	1,514
77	60.6	135,563	93,403	421	59.4	59,225	39,815	437
43	77.0	224,053	227,971	711	60.8	163,678	44,251	489
31	84.7	148,355	131,587	443	67.6	353,399	90,029	1,214
26	89.0	146,874	151,999	349	71.6	374,166	209,832	1,464

TABLE NO. 73.—*Bacteria remaining at various sampling stations, lower Illinois River, corrected for tributary inflow and cities, expressed in percentages of the maximum and with times of flow below this maximum*

Sampling station	Time of flow in hours from station 148	Per cent of maximum remaining (corrected for additions by tributaries and cities)			Time of flow in hours from station 148	Per cent of maximum remaining (corrected for additions by tributaries and cities)		
		Gelatin	Agar	B. coli		Gelatin	Agar	B. coli
	(a) Summer season				(b) Winter season			
148	0	100.00	100.00	100.00	0	100.00	100.00	100.00
122	23.0	23.97	23.07	17.24	17.7	69.05	40.23	50.00
101	45.1	9.107	12.32	3.515				
89	56.0	9.118	11.33	3.544				
84	62.1	6.034	7.467	0.0881				
78	68.5	10.73	12.08	0.0953				
43	93.4	5.317	4.196	0.3763	72.2	77.72	31.58	12.41
31	102.3	3.348	2.406	0.2071	80.1	77.67	31.17	12.47
26	107.9	3.944	3.182	0.2239	84.5	81.84	36.71	10.22
	(c) Summer transitional season				(d) Winter transitional season			
148	0	100.00	100.00	100.00	0	100.00	100.00	100.00
122	18.4	32.23	33.40	42.78	16.8	54.93	50.78	29.88
101	40.2	17.42	16.05	23.56	38.9	15.85	26.60	32.62
89	50.2	22.06	19.31	14.17	49.0	16.79	23.21	38.08
77	60.6	14.89	14.52	6.491	59.4	11.88	18.54	10.99
43	77.0	24.60	35.45	10.96	60.8	32.84	20.61	12.30
31	84.7	16.29	20.46	6.830	67.6	70.91	41.92	30.53
26	89.0	16.13	23.64	5.381	71.6	75.07	97.71	36.8

An inspection of these data shows that, as before observed, the maximum numbers of bacteria do not occur immediately below the sewer outlets of Peoria at station 153 but increase from that point to station 148, where the highest concentration was found. Sampling stations are not sufficiently close together in this part of the river to define the possible extension of this increase to points farther downstream during colder weather, the maximum observed for all seasons being at station 148. This point is therefore taken as the base from which rates of bacterial decrease are computed.

Considering now the agar count observations for the summer season plotted as before on semilogarithmic paper, with respect to time, they indicate a quite orderly rate of change, with the exception of one station where observations extend over a few months of the summer of 1921 only. The rate of decrease is evidently more rapid at the higher concentrations, decreasing progressively as the water passes downstream. Observation stations are not sufficiently close to accurately define the path of decrease immediately below the maximum, though at the end of the first 23 hours there remain only 23 per cent of the bacteria present at this maximum point. For the winter months the rate is noticeably less, and after about 50 hours a stable condition seems to have been reached below which no further decrease was noted. This same condition of stabilization obtains in the summer transitional period as well as in that of the winter. However, our observations at the lower stations for these periods are probably improperly corrected because of the excessive floods occurring in the lower Illinois Valley during the months of April and May, 1922, when undetermined amounts of surface pollution were washed into the streams from all parts of the watershed. Accordingly the rates of decrease during these times are probably subject to a wide range of error.

CURVES DEFINING AVERAGE RATES OF PURIFICATION

Since the observed data tend to fall along reasonably regular lines, defining the rates at which bacteria are decreasing, as was found to be the case in the upper river, smooth curves, drawn by inspection, are presented in Figures 30 to 32, suggesting in a general way the definite rates at which such reduction may be supposed to proceed. Such rates must be taken as approximate only, but, as defined by our observations, fairly representative of the actual conditions then existing. These graphic rates of change may also be expressed in the form of tables, by reading the ordinates from the curves, corresponding to definite times of flow from the point of maximum concentration. Such general rates of decrease are given in Table No. 74.

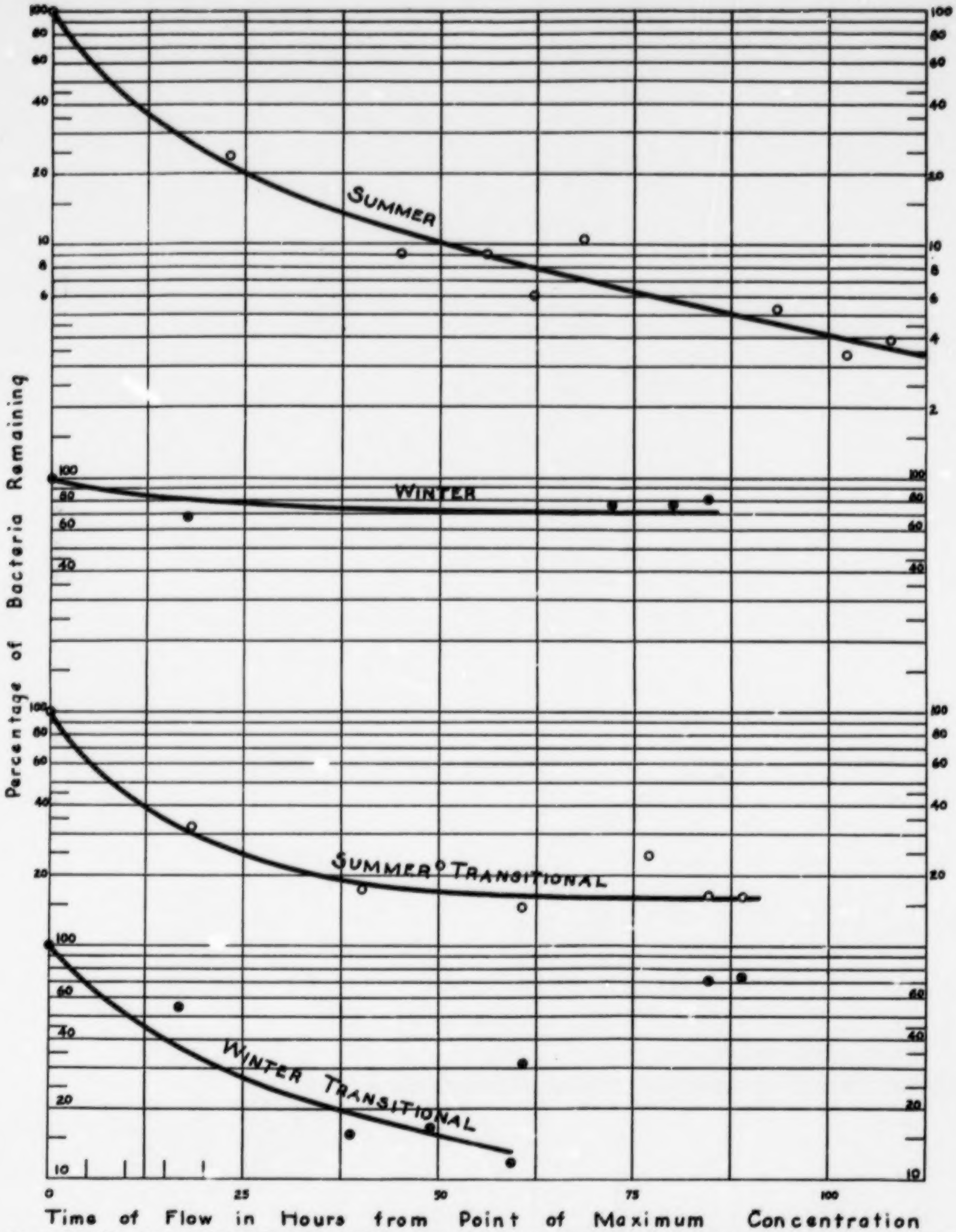


FIG. 20.—Bacterial purification in the lower Illinois River in relation to time of flow from zone of maximum pollution. Gelatin counts, summer, winter, summer transitional and winter transitional seasons

44602—27. (Face p. 102.) No. 1

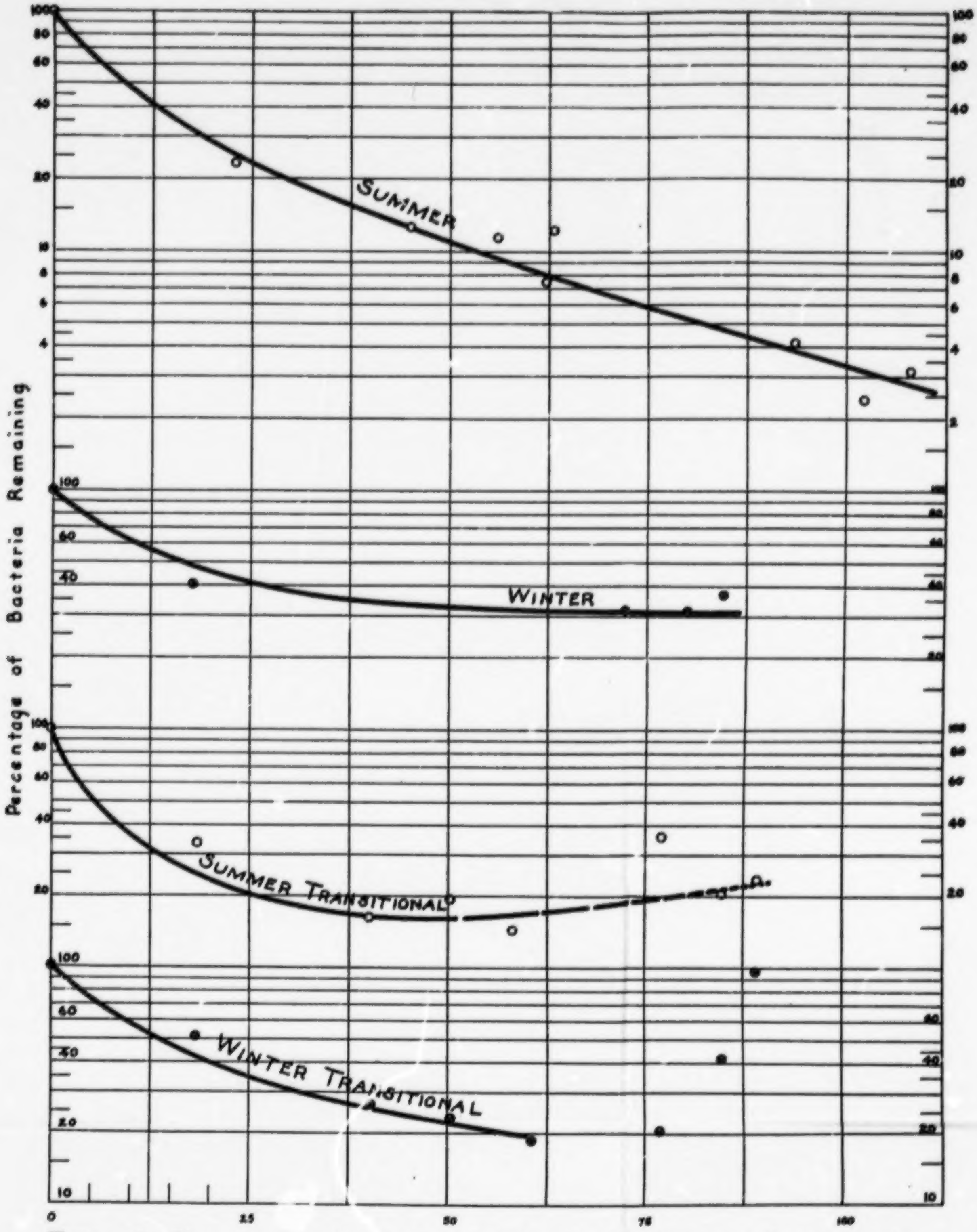


Fig. 31.—Bacterial purification in the lower Illinois River in relation to time of flow from zone of maximum pollution. Agar counts, summer, winter, summer transitional and winter transitional seasons

44602—27. (Face p. 192.) No. 2

192c

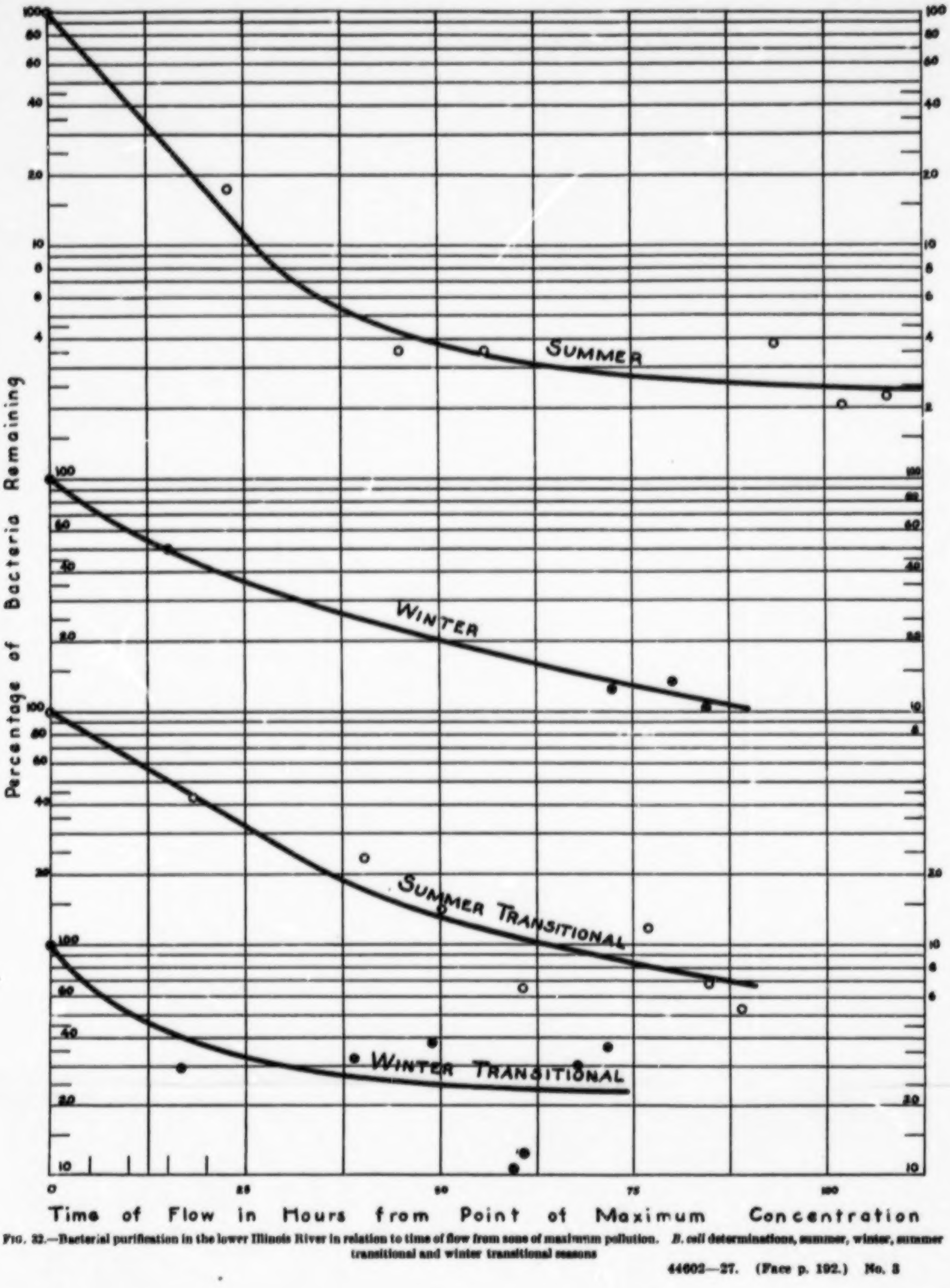


FIG. 32.—Bacterial purification in the lower Illinois River in relation to time of flow from zone of maximum pollution. B. coli determinations, summer, winter, summer transitional and winter transitional seasons

TABLE No. 74.—*Coordinates of curves describing decrease in gelatin counts, agar counts and B. coli, in relation to time of flow from zone of maximum pollution, lower Illinois River*

Time of flow from maximum, in hours	Percentage of bacteria remaining					
	Summer season			Winter season		
	Gelatin count (maximum per cubic centimeter =281,000)	Agar count (maximum per cubic centimeter =254,000)	B. coli (maximum per cubic centimeter =3,730)	Gelatin count (maximum per cubic centimeter =29,000)	Agar count (maximum per cubic centimeter =9,440)	B. coli (maximum per cubic centimeter =180)
0	100.0	100.0	100.0	100.0	100.0	100.0
5	61.0	65.5	64.5	91.0	78.0	78.0
10	41.8	47.5	41.8	86.0	61.5	60.0
20	24.9	28.6	17.5	80.0	45.9	42.0
30	16.9	19.8	7.55	76.0	38.0	31.0
40	12.8	14.7	4.90	73.5	34.3	25.0
50	10.3	11.0	3.73	72.0	32.6	20.2
60	8.28	8.50	3.19	71.0	31.4	16.8
70	6.95	6.68	2.87	71.0	31.0	14.0
80	5.80	5.28	2.68	71.0	31.0	11.9
90	4.85	4.19	2.57	71.0	31.0	10.2
100	4.10	3.34	2.49	....	....	....
125	2.73	1.90	2.38	....	....	....

Time of flow from maximum in hours	Percentage of bacteria remaining					
	Summer transitional season			Winter transitional season		
	Gelatin count (maximum per cubic centimeter =44,700)	Agar count (maximum per cubic centimeter =36,200)	B. coli. (maximum per cubic centimeter =408)	Gelatin count (maximum per cubic centimeter =18,300)	Agar count (maximum per cupic centimeter =10,600)	B. coli. (maximum per cubic centimeter =188)
0	100.0	100.0	100.0	100.0	100.0	100.0
5	61.0	52.0	80.0	68.8	73.5	65.5
10	44.5	36.1	62.8	51.2	57.9	50.7
20	28.7	23.3	40.8	32.8	39.8	38.7
30	22.0	18.5	26.0	23.8	31.3	30.0
40	18.7	16.6	17.5	18.7	25.7	26.8
50	17.2	16.2	13.2	15.4	22.1	24.9
60	16.6	16.0	10.7	12.9	19.3	24.0
70	16.0	....	8.85	....	....	....
80	16.0	....	7.50	....	....	....
90	16.0	....	6.70	....	....	....
100	16.0	....	....	....	....	....

COMPARISON OF DERIVED CURVES OF PURIFICATION RATES WITH THOSE OF THE OHIO RIVER

A comparison of the curves above derived defining the rates of bacterial purification in the upper and the lower Illinois and of similar curves for the Ohio River [5] shows that, starting at the point of maximum concentration on the two sets of curves, and disregarding the concentration of bacteria, the various rates of bacterial decrease are not comparable. These rates, as well as the concentrations of bacteria, in the upper Illinois, are very much higher than those in the lower Illinois or in the Ohio. Taking first the summer agar curves as well as the winter curves for the three river sections, this considerable divergence in rates may be readily observed in Figure 33 where all the curves start from the same origin of 100 per cent, the point of maximum bacterial content in each case. However, it will be noted that the maximum concentration of bacteria in the upper Illinois is much greater than in the other two cases. When these differences in bacterial density are taken into consideration and comparisons made at points where the concentrations are equal, a closer correlation is obtained.

---

[5] Public Health Bulletin 143, Tables Nos. 126 and 127.

Such a comparison has been made for the summer agar and the summer *B. coli* curves in Figure 34. The maximum concentration of bacteria growing on agar on the upper Illinois for summer was 3,420,000 bacteria per cubic centimeter, while the corresponding concentration for the Ohio River was 99,300 per cubic centimeter, or 2.9 per cent of the Illinois. Therefore the 100 per cent point on the Ohio River agar curve was adjusted to 2.9 per cent and proportional changes made on all of the other points. This point of 2.9 per cent on the Illinois River curve corresponds to a time of 63 hours from the point of origin. Therefore to adjust the corresponding times on the Ohio curve, 63 hours were added in each case to the Ohio River times of flow. The method of adjustment is illustrated in detail in Table No. 75 and the adjusted curves are plotted in Figure 34.

TABLE No 75.—*Comparison of coordinates of bacterial purification rates, Illinois River and Ohio River, agar counts, summer season*

Adjustment of coordinates							Per cent remaining upper Illinois River
Time from maximum, hours as derived	Time from maximum, hours, adjusted to upper Illinois		Per cent remaining				
			As derived		As adjusted		
	Lower Illinois	Ohio River	Lower Illinois	Ohio River	Lower Illinois	Ohio River	
0	36.5	63	100	100	7.43	2.90	100
10	46.5	73	47.5	67.26	3.53	1.95	27.5
20	56.5	83	28.6	45.37	2.12	1.32	14.8
40	76.5	103	14.7	20.90	1.09	.606	6.28
60	96.5	123	8.50	9.86	.632	.287	3.69
80	116.5	143	5.28	4.89	.393	.148	2.19
100	136.5	163	3.34	2.56	.248	.0742	1.37
125	161.5	188	1.90	1.30	.141	.0377	.735
150	----------	213	----------	.759	----------	.0220	.425
175	----------	238	----------	.502	----------	.0146	.289
200	----------	263	----------	.362	----------	.0105	.125

Maximum concentration upper Illinois equals 3,420,000 per cubic centimeter.
Maximum concentration lower Illinois equals 254,000 per cubic centimeter equals 7.43 per cent of upper Illinois.
Maximum concentration Ohio River equals 99,300 per cubic centimeter equals 2.90 per cent of upper Illinois.

The same type of adjusted curves of the rates of decrease in bacteria growing on gelatin during he summer months is shown in Figure 20. While the adjusted rates of decrease do not coincide, due to the greater intensity of reduction in each case immediately following the attainment of the maximum concentration, yet they exhibit quite closely the same general trend.

194a

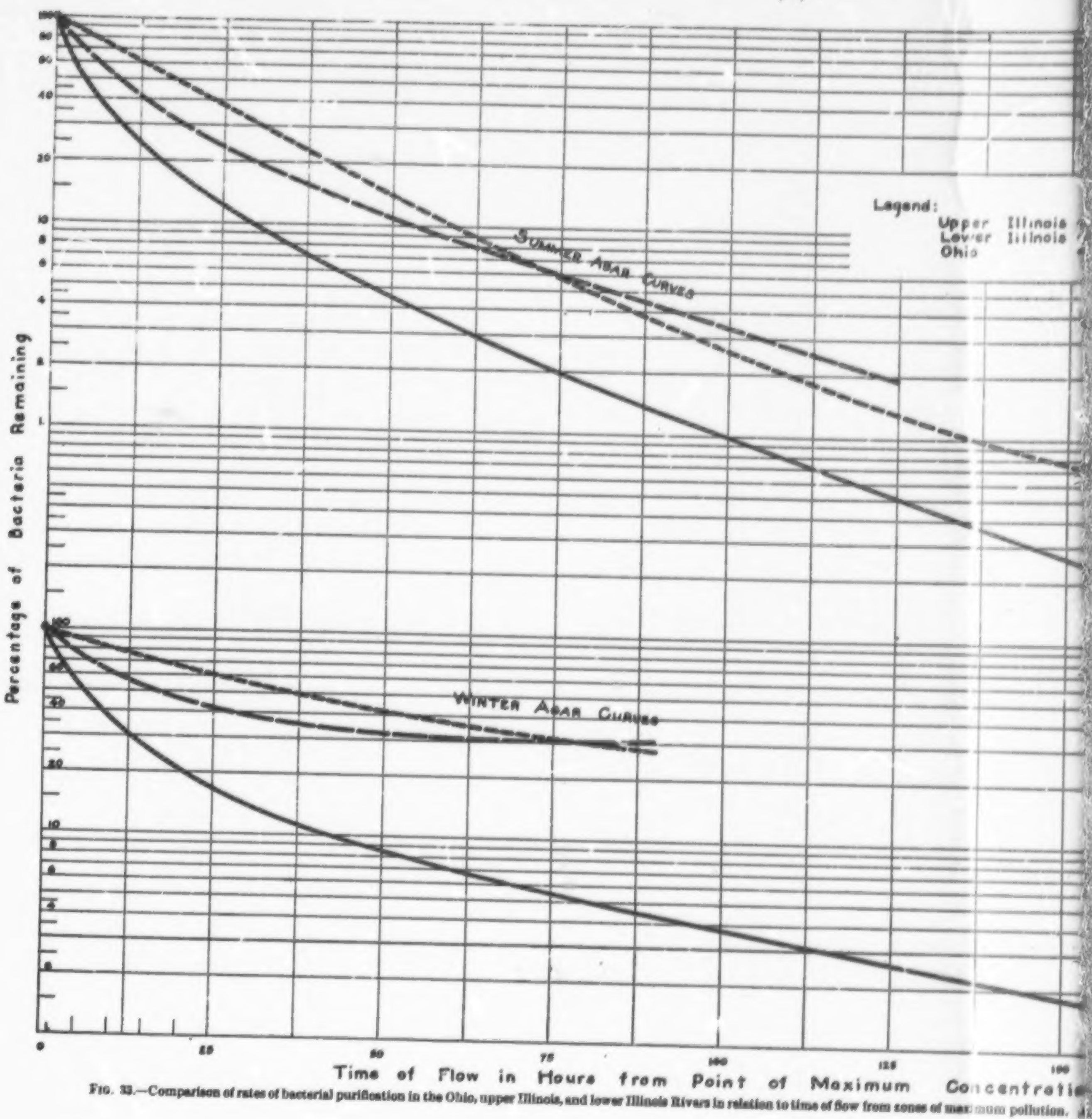
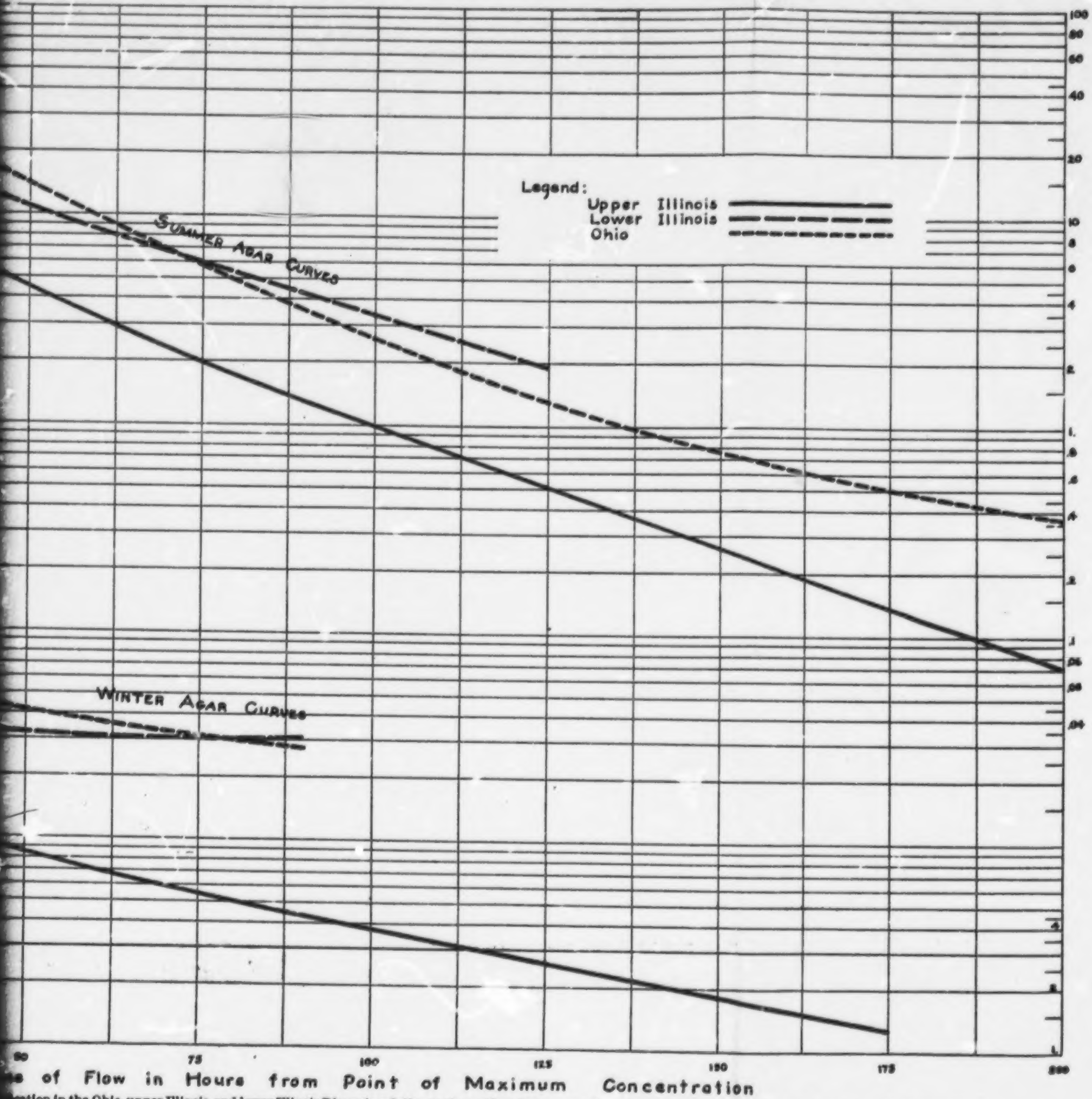


FIG. 33.—Comparison of rates of bacterial purification in the Ohio, upper Illinois, and lower Illinois Rivers in relation to time of flow from zones of maximum pollution.

194a



cation in the Ohio, upper Illinois, and lower Illinois Rivers in relation to time of flow from zones of maximum pollution. Agar counts, summer and winter seasons

44602—27. (Face p. 194.) No. 1

194b

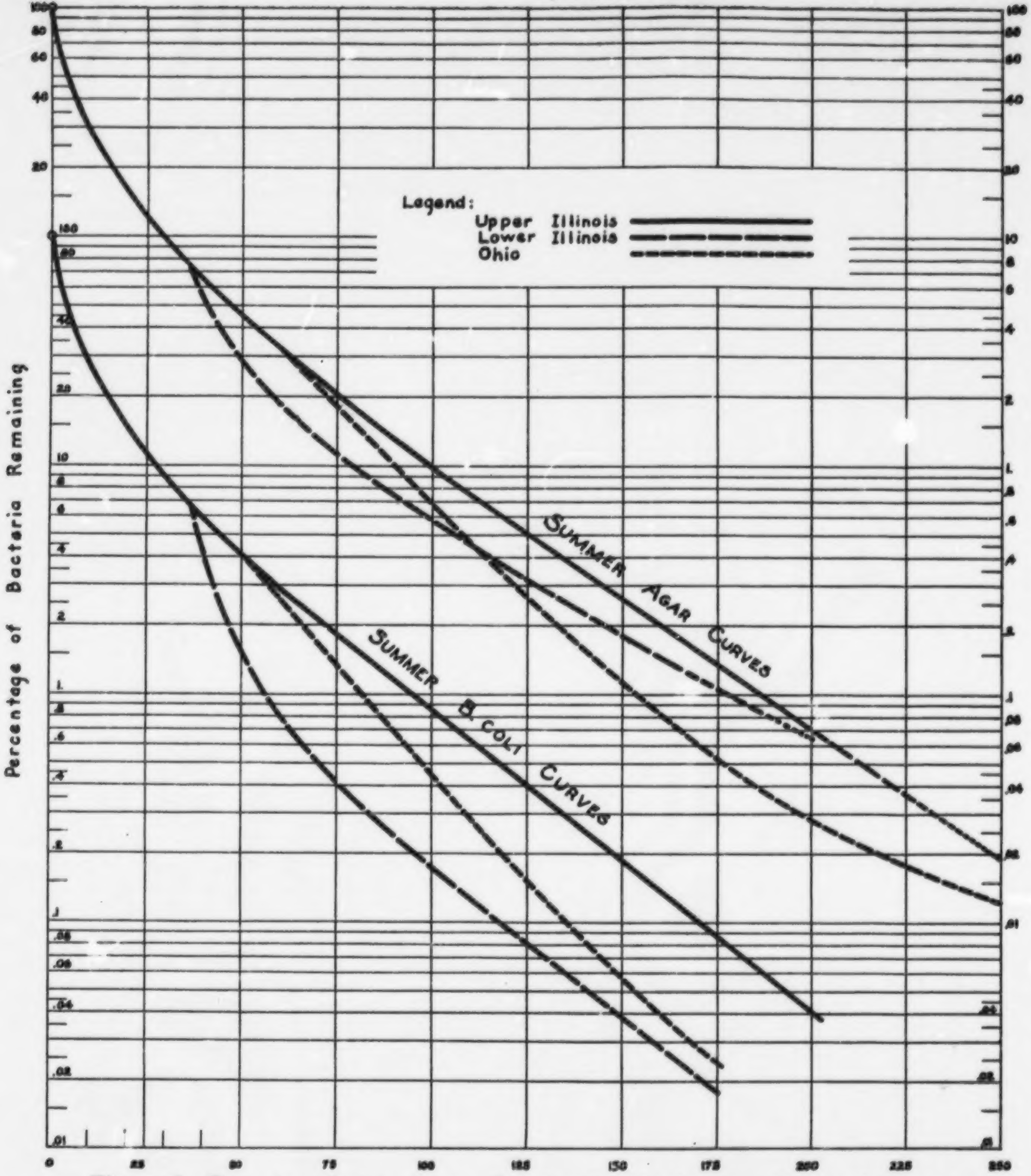


FIG. 34.—Comparison of rates of bacterial purification in the Ohio, upper Illinois, and lower Illinois Rivers in relation to times of flow from zones of equal concentration. Agar counts, summer months, and *B. coli* determinations, summer months

44602—27. (Face p. 194.) No. 2

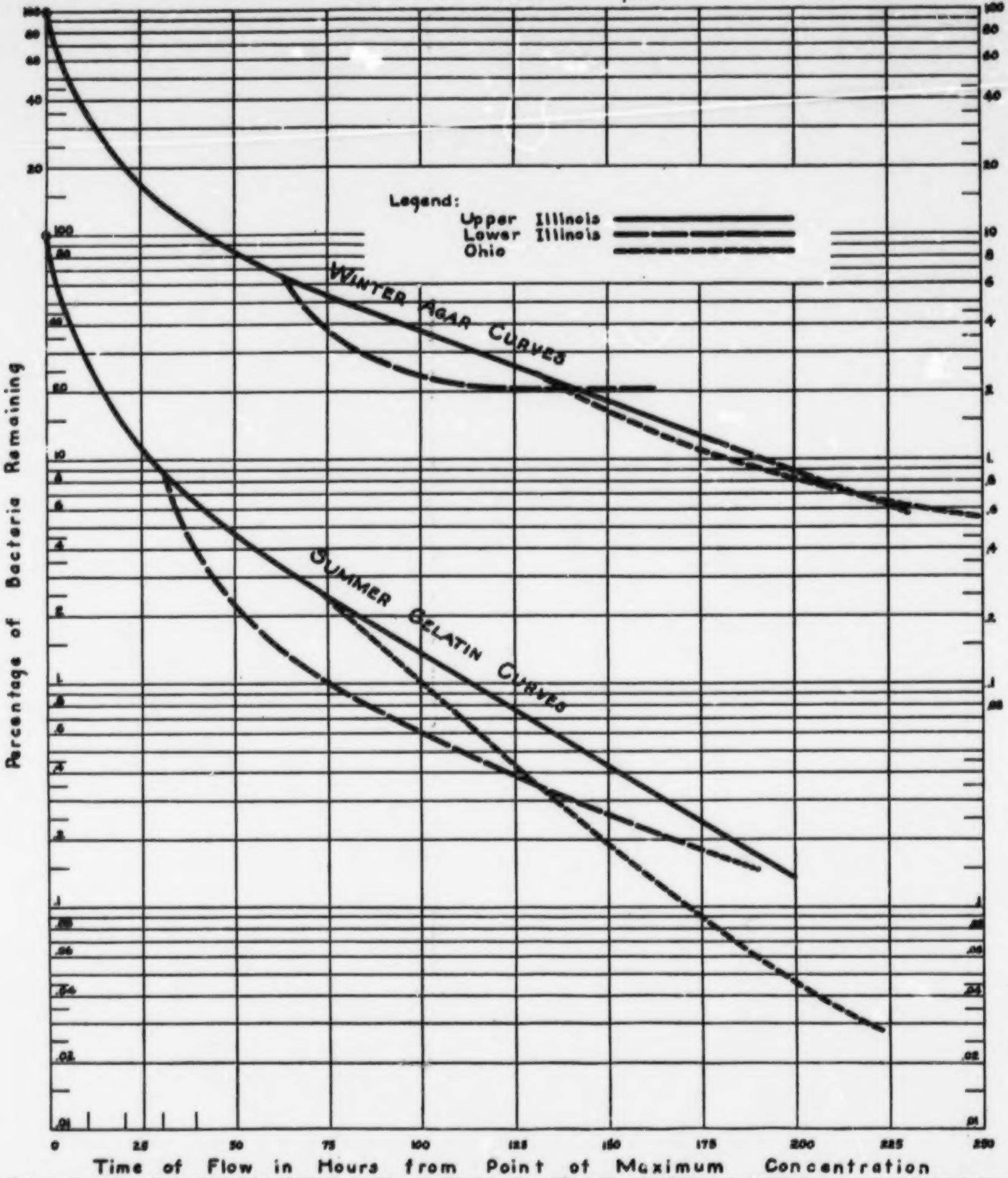


FIG. 35.—Comparison of rates of bacterial purification in the Ohio, upper Illinois, and lower Illinois Rivers in relation to times of flow from zones of equal concentration. Agar counts winter months, and gelatin counts, summer months

44602—27. (Face p. 195.)

Similar comparisons of the winter agar curves and of summer gelatin curves are shown in Figure 35 wherein the adjustment of values on the basis of initial density tends to bring the rates into closer harmony.

By adjusting the coordinates of the rates of purification for corresponding bacterial determinations and seasons and plotting the adjusted curves as in Figures 34 and 35 corresponding ordinates may be read on each of the several curves for stated times of flow. Such readings are presented in Table No. 76, wherein the corresponding gelatin, agar and *B. coli* rates of decrease are compared for the summer season and the agar rates for the winter.

TABLE No. 76.—*Comparison of coordinates of bacterial purification curves, Illinois and Ohio Rivers, adjusted for equivalent concentrations*

Time from maximum, hours	Percentage remaining											
	Summer season									Winter season		
	Gelatin			Agar			B. coli			Agar		
	Upper Illinois	Lower Illinois	Ohio River	Upper Illinois	Lower Illinois	Ohio River	Upper Illinois	Lower Illinois	Ohio River	Upper Illinois	Lower Illinois	Ohio River
0	100			100			100			100		
10	27.5			28.5			28.6			36.3		
20	14.3			15.8			14.3			26.7		
31.5	8.50	8.50										
36.5				7.43	7.43							
37.0							6.52	6.52				
40	6.26	3.80		6.80	5.25		5.86	3.80		10.6		
50.5							4.09		4.00			
60	3.50	1.52		3.21	3.25		2.95	.80	2.58	7.00		
62.5										6.65	6.65	
68				2.90		2.90						
73.5	2.54		2.54									
80	2.19	.90	2.09	1.70	.97	1.50	1.58	.34	1.06	5.08	3.20	
100	1.37	.60	1.00	.990	.57	.692	.861	.17	.44	3.78	2.34	
125	.766	.30	.43	.505	.315	.262	.406	.061	.158	2.62	2.09	
150										2.47		2.47
160	.425	.26	.19	.262	.180	.111	.186	.088	.038	1.82	2.09	1.65
175	.239	.18	.090	.136	.107	.053	.067	.016	.025	1.27	2.09	1.10
200	.135		.046	.071		.028	.041					.83

During the winter months the bacterial concentrations of the three streams are quite widely divergent, and the rates of purification such that points of equal density for gelatin counts and for *B. coli* did not occur within the observed time-of-flow range and hence can not be compared on that basis.

While such a comparison of these rates appears to indicate the varying effect of initial density on the velocity of decrease in bacteria the coincidence of the curves thus adjusted is not especially striking. It is entirely possible that the bacterial death rate in streams is some function of the initial density and that, in general, the degree of bacterial purification can be more accurately described by a family of curves, having their maximum points at a common origin with respect to time and at ordinates corresponding to the bacterial density at such maximum. For the determination of such a family of curves, observations on a considerable number of streams would aid in verifying the existence of this type of a general law of bacterial purification.

GENERAL SUMMARY

In pursuance of its policy in research investigations of the phenomena of stream pollution and rates of natural purification of polluted water, the United States Public Health Service, in cooperation with the Sanitary District of Chicago, instituted a study of the Illinois River, the field work of which was carried out during the years 1921–22. Surveys were made to ascertain the sources and amounts of polluting materials discharged to the stream. Hydrographic features of the river and its principal tributaries were ascertained and observations were made over a period of about a year to determine the chemical, bacteriological, and biological condition of the river water throughout the stream length.

The watershed of the Illinois River, comprising a total area of 28,344 square miles, is a part of the eastern Mississippi drainage basin and comparatively flat. The natural drainage area has been increased by the construction of the main drainage canal of the Sanitary District of Chicago which, by reversing the flow of the Chicago River, withdraws water from Lake Michigan and discharges it into the headwaters of the Illinois River near Joliet. The natural volume of flow of the river is thus greatly augmented and, as this canal also transports the major volume of sewage of the Sanitary District of Chicago, it contributes a very heavy burden of pollution to the headwaters of the stream. Thus of a total sewered population on the watershed of nearly 3,400,000, over 80 per cent, or approximately 2,800,000, contribute sewage through the canal. In like manner the greater proportion of industrial waste pollution added to the river amounting, in terms of population equivalents, to about 67 per cent of the total of the watershed, originates from the same source.

The volume of flow in the main drainage canal, although fluctuating from hour to hour, was maintained at a relatively constant average rate of discharge during the time of the field studies, averaging 8,650 cubic feet per second for the entire period and amounting to over 30 per cent of the total discharge of the Illinois River at the lowest station of observation, 26 miles from the mouth. However, this percentage contribution to the total Illinois River discharge varies considerably with changing amounts of run-off from the drainage area; thus in July, 1921, 70.7 per cent of the total river flow was added by the canal, while in April, 1922, a month of excessive river floods, only 9.3 per cent of the total volume of river water originated from this source.

This proportionately large and relatively constant volume of water discharged into the upper reaches also has the effect of stabilizing the velocity of flow in the Illinois River to a marked extent. Computations of the time of passage of water from Joliet to Peoria, a distance of 120 miles, indicate that the average for the year is 179 hours, ranging from a maximum of 188 hours to a minimum of 175 hours, with the sole exception of one month of excessive floods when the time was reduced to 131 hours. In the lower reaches of the river where the combined inflow constitutes a larger percentage of the total discharge, the times of flow are proportionately affected. Thus the time of passage from Peoria to the lowest station of observation averaged, for the year, 114 hours and varied between 147 and 79 hours for months of low and high run-off, respectively. However, these average times of flow are seriously affected and in fact become quite indeterminate at times of excessive run-off when the stream overtops its banks and floods the considerable areas of adjoining lowlands which act as equalizing reservoirs for the surplus water coming to them.

For the purpose of observing changes in the chemical and bacterial content of the river water throughout the length of the stream, sampling stations were located at established points and at intervals usually not exceeding 25 miles apart, from which places specimens were regularly collected three or six times each week. These samples were promptly transported to the most accessible of four laboratories especially equipped for these studies, and there examined in accordance with standard methods of procedure. Samples were likewise collected from the mouths of the larger tributaries for the purpose of ascertaining their contributions to the water of the main stream. Such collections and examinations were continued over a period of 14 months to observe the conditions throughout a complete seasonal cycle. Chemical analyses comprised determinations of turbidity, alkalinity, and dissolved oxygen both immediate and after five days incubation at 20° C. on all samples received; suspended matter was determined in samples from selected points. Determinations of free ammonia, Kjeldahl nitrogen, nitrogen oxides, and oxygen consumed were made on composite samples collected from selected sampling stations and preserved with sulphuric acid.

The bacteriological examination of all samples consisted of the determination of the numbers of bacterial colonies growing on agar plates incubated at 37° C. for 24 hours and on gelatin plates incubated at 20° C. for 48 hours, together with an estimation of the numbers of *B. coli*, all in practical accordance with standard procedures established by the American Public Health Association.

Samples of both the river water and of bottom sediments were also regularly collected from selected locations for determination of the plankton content. Such samples were concentrated at the laboratory at which they were received, preserved with formalin and later examined at the Cincinnati station of stream pollution investigations. The results of these plankton observations are discussed in a separate forthcoming publication.

The sanitary chemical analyses afford a means of estimating roughly the extent of dilution of Chicago sewage in the main drainage canal by water drawn from Lake Michigan. From these data it appears that from 7 to 8 per cent of the flow in the canal is sewage of normal strength diluted with lake water in amounts from 93 to 92 per cent. The changes in amounts of chemical constituents at successive downstream points are generally not marked and frequently within the limits of error of determination, and in such cases of no significance. It appears that no nitrates are produced in the river above Peoria, especially during the summer months. The amounts of total nitrogen appear to be reasonably constant throughout the year, which is also true of the value of oxygen consumed. As a whole it may be concluded that the sanitary chemical determinations are not sufficiently sensitive to record, accurately, progressive changes that occur in the waters of polluted streams as they flow from point to point. Such examinations are of value, however, in a general way for comparative purposes.

The oxygen dissolved and the oxygen demand determinations are more sensitive indices of the existing condition of organic substances that cause nuisance in polluted watercourses. Such determinations were consistently made of all samples collected, the average results for which are included in the tabulated data of this report. A discussion of these observations has been reserved for later consideration.

The numbers of bacteria in water, especially those of the *B. coli* group, are generally considered an index of its sanitary condition. Being exceedingly sensitive to various factors of environment, it is of considerable interest to have definite knowledge of the rates at which they disappear in polluted streams or, in other words, the nature and extent of occurrence of natural bacterial purification under various seasonal and physical conditions to which the stream is subjected. The bacteriological observations were, therefore, made with this object in view and for the further purpose of comparing such results with those obtained in previous similar studies of the Ohio River.

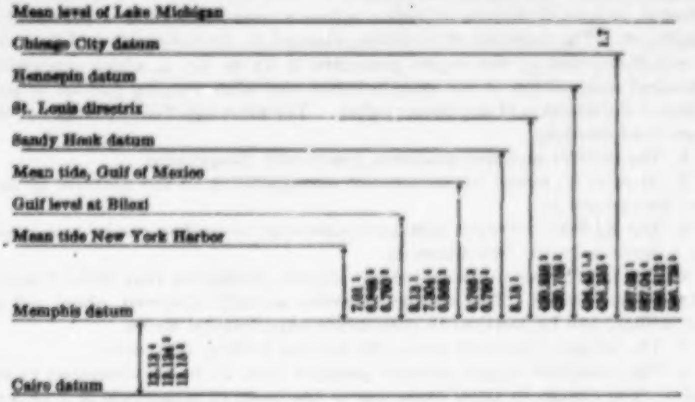
Observations, continued throughout an entire year, of the bacterial content of the Illinois River at definitely established sampling stations have supplied sufficient information to evaluate the excessive bacterial pollution of the river by the main drainage canal of Chicago. The density of bacteria is very rapidly reduced in the upper reaches of the river, and, progressing downstream, at slower rates until at Peoria the average numbers growing on agar seldom exceed 4,000 per cubic centimeter in summer and 2,000 in winter. Pollution contributed by the Peoria district again imposes a considerable bacterial load on the stream, which likewise tends to diminish at subsequent downstream points, until at the mouth the bacterial content of the Illinois compares quite closely with that of the Mississippi River at the junction.

The rates at which the bacteria decrease are dependent on seasonal temperatures, being much more rapid in summer than in winter. When necessary corrections are made for pollution added by tributaries and intermediate cities, these rates are quite well described by the observational data, and may be defined, in general, by smooth curves fitted to the observations and plotted with respect to the time of flow elapsing between successive sampling points. Such curves, while having the same general characteristics as those found to fit similar observations made on the Ohio River, are yet distinctive in that the initial rates of decrease are more precipitous as a rule. However, when the differences in initial concentrations are taken into consideration and the curves adjusted for this condition, they are more nearly comparable.

APPENDIX A

RELATION OF VARIOUS DATUM PLANES OF THE MISSISSIPPI RIVER VALLEY

The relation of the various established datum planes of the Mississippi River Valley according to various authorities is shown in the following diagram (figures are in feet):



Mean level of Lake Michigan
Chicago City datum
Hennepin datum
St. Louis directrix
Sandy Hook datum
Mean tide, Gulf of Mexico
Gulf level at Biloxi
Mean tide New York Harbor
Memphis datum
Cairo datum

---

[1] According to State water survey.
[2] According to last corrected records, June, 1906, Mississippi River Commission.
[3] According to last corrected records, June, 1906, Coast and Geodetic Survey.
[4] According to report of Corps of Engineers, U. S. Army, Fifty-ninth Congress, first session, House of Representatives, Document No. 263.

In the computations of the Illinois River investigation, 1921–22, all elevations were referred to Memphis datum. The relations selected for making reductions between the various planes are shown in the following table:

Datum	Elevation in feet above—					
	Chicago City	Hennepin	Sandy Hook	Gulf level	Memphis	Cairo
Cairo	−600.16	−447.58	−21.31	−21.26	−12.13	0
Memphis	−587.03	−434.45	−8.18	−8.13	0	12.13
Gulf level	−578.90	−426.32	−.05	0	8.13	21.26
Sandy Hook	−578.85	−426.27	0	.05	8.18	21.31
Hennepin	−152.58	0	426.27	426.32	434.45	447.58
Chicago	0	152.58	578.85	578.90	587.03	600.16

Preceding page blank

APPENDIX B

PRESERVATION OF SAMPLES FOR SANITARY CHEMICAL ANALYSIS

By Chemist E. J. Theriault

The procedure of compositing samples for sanitary chemical analysis over a 10-day period, while highly satisfactory in view of the economy of time and labor effected, is open to serious objection unless a suitable method of preservation is employed. The necessity of inhibiting changes in the composition of the samples is well illustrated by the results presented in Table No. 1, which represent the chemical composition of the sample before and after varying periods of storage without the addition of any preservative. The most significant changes observed were the following:

1. The nitrites and free ammonia practically disappeared.
2. Nitrates increased by an amount corresponding to the decrease in nitrites and free ammonia.
3. The Kjeldahl nitrogen decreased somewhat more than can be accounted for by a decrease in the free ammonia.
4. The total nitrogen decreased but slightly, indicating that little, if any, free nitrogen is formed. The average decrease actually observed, about 0.2 parts per million, can be ascribed to cumulative experimental errors.
5. The oxygen consumed value (30 minutes boiling) decreased.
6. The dissolved oxygen content (samples Nos. 21 to 25) decreased considerably. The change in these cases was of the order of magnitude of 7 or 8 parts per million, while the corresponding changes in the other determinations were in the neighborhood of 1 or 2 parts per million at a maximum. The great sensitiveness of the oxygen demand results follows from the fact that a change in the value of this constituent represents the sum of a number of changes. Thus, denoting a change in the oxygen demand value by the symbol D(O.D.); $D(O.D.)=K_1\ D(NO_2)+K_2\ D(NH_4)+K_3\ D$ (oxygen consumed, etc.) where $D(NO_2)$=change in nitrite content, etc. The exact numerical values of the constants K_1, K_2, etc., are, of course, very uncertain, but in some cases these values may be fairly large.

TABLE No. 1.—*Changes in the chemical composition of samples stored 10 to 15 days without the addition of any preservative*

[Results in parts per million]

Sample No.	Nitrites		Nitrates		Free ammonia		Kjeldahl nitrogen		Oxygen consumed		Dissolved oxygen content	
	Fresh	*Stored*	*Fresh*	*Stored*	*Fresh*	*Stored*	*Fresh*	*Stored*	*Fresh*	*Stored*	*Fresh*	*Stored*
1	0.08	0.000	0.4	1.5	1.4	0.0	3.6	1.8	5.8	2.6		
2		.000	.3	1.2	1.6	.2	2.4	1.4	4.4	3.2		
3	.08	.010	.7	2.0	1.4	.3	3.4	2.4	4.4	3.3		
4	.07	.000	.7	1.6	1.5	.6	3.6	1.6	4.6	3.6		
5	.08	.005	.9	2.2	1.0	.0	2.4	1.6	4.0	3.0		
6		.005	1.2	1.5	1.1	.3	3.2	1.8	4.2	3.3		
7	.10	.000	1.4	2.3	1.1	.6	2.4	1.8	4.2	3.5		
8	.14+	.000	1.4	2.7	.9	.6	2.8	2.0	4.7	4.4		
9	.14+	.005	1.4	2.0	.9	.1	2.6	1.8	4.7	3.8		
10	.12	.000	1.2	2.7	.8	.0	2.6	1.8	5.1	4.0		
11	.12	.040	1.0	2.7	.8	.0	3.2	2.6	4.6	4.0		
12	.13	.010	1.0	2.7	.8	.2	3.0	1.8	4.5	3.8		
13	.11	.000	1.3	2.3	.8	.0	3.2	2.2	4.3	4.4		
14	.10	.000	1.6	2.8	.8	.0	2.8	1.8	5.4	3.6		
15	.10	.005	1.4	3.0	.8	.0	3.2	1.6	5.8	3.6		
16	.10	.005	1.4	3.0	.7	.0	4.6	2.2	4.6	3.6		
17	.10	.005	2.0	3.7	.5	.1	3.0	1.8	4.7	3.8		
18	.07	.000	1.3	2.3	.8	.0	3.0	1.6	5.6	7.5		
19	.07	.000	1.4	2.2	.9	.6	2.4	.8	5.2	4.7		
20	.07	.005	1.4	2.0	.9	.0	2.4	1.0	4.9	4.2		
21	.10	.020	1.2	1.5	1.0	.2	2.2	.5	4.3	4.2	8.3	6.3
22	.06	.005	1.4	2.4	1.0	.0	2.0	.5	5.4	3.5	8.6	.1
23	.10	.005	1.9	2.8	.7	.3	1.8	.3	4.5	4.0	8.2	.0
24	.07	.010	1.5	2.8	.8	.3	1.8	.4	4.8	3.7	7.8	1.0
25	.15	.005	2.6	4.0	.5	.0	1.6	.4	5.1	3.6	7.7	1.7
Averages	.09	.006	1.5	2.4	.9	.08	2.8	1.5	4.8	4.0	8.1	.6

These results clearly indicate not only the extent of the change in the chemical composition of the samples, but also the limitations of the methods themselves.

EFFICACY OF ACIDIFICATION AS A METHOD OF PRESERVATION

A series of 25 tests is available for the purpose of estimating the efficacy of acidification as a method of preserving river samples for analysis. The analytical procedures used did not differ essentially from the Standard Methods of the American Public Health Association (1920). On reaching the laboratory, the samples were divided in two portions, one of which was treated with acid. The two portions were then analyzed separately, giving values which will be designated by Z_1 and Z_2. Since the relative volume of added acid was very small, these two values may be regarded as strict duplicates. The samples were then stored in the light at ordinary temperatures and, after intervals of time ranging from 5 to 25 days, the acidified portion was again analyzed, the values obtained being designated by the symbols Z_3, Z_4, and Z_5, etc. If acidification is truly effective, the values corresponding to any given sample should be somewhat alike.

By reference to Table No. 2, where the free ammonia results have been summarized, it is apparent that prolonged storage was entirely without effect on the free ammonia content of acidified samples. These results are also of interest, inasmuch as they are typical of the precision attainable when Nessler readings are uncomplicated by other sources of error.

TABLE No. 2.—*Constancy of the free ammonia content of acidified river water*

[Results in parts per million]

Sample No.	Fresh samples		Stored samples, acidified		
	Not acidified, Z_1	Acidified, Z_2	5 to 10 days, Z_3	10 to 15 days, Z_4	15 to 20 days, Z_5
1	1.4	1.4	1.3	1.3	1.4
2	1.6	1.6	1.3	1.3	1.5
3	1.3	1.3	1.3	1.7	----------
4	1.5	1.5	1.1	1.3	----------
5	1.0	1.0	1.3	1.3	1.3
6	1.1	1.2	1.0	1.2	1.3
7	1.1	1.1	1.2	1.0	----------
8	.9	1.2	1.0	1.0	----------
9	.9	1.0	1.1	1.1	----------
10	.8	.8	.8	.8	----------
11	.8	.8	----------	1.0	----------
12	.8	.8	----------	.9	----------
13	.8	.7	.7	----------	.8
14	.8	.8	----------	----------	.8
15	.8	.9	----------	.8	.9
16	.7	.7	----------	.8	.9
17	.5	.8	----------	.5	.8
18	.6	.8	.8	.6	.8
19	.9	.9	.7	.8	----------
20	.9	.8	----------	.8	.7
21	1.0	1.0	1.0	1.0	.9
22	1.0	1.0	1.0	1.0	1.0
23	.7	.7	.8	.8	.7
24	.8	.8	.8	.8	.7
25	.8	.6	.8	.7	.6

Parallel determinations of the nitrite content of acidified samples are presented in Table No. 3. It is apparent that acidification is totally ineffective for the purpose of preventing changes in the nitrite content of river water samples. However, as the nitrite content of the samples is always relatively small in comparison with the nitrate content, and because the significance of these two forms of nitrogen is very much the same, the results have been combined under the heading "nitrogen oxides." In the presence of oxygen the sum of these two forms of nitrogen should be sensibly constant.

TABLE No. 3.—*Changes in the nitrite content of acidified river water*

[Results in parts per million]

Sample No.	Fresh samples		Stored samples, acidified			
	Not acidified, Z_1	Acidified, Z_2	5 to 10 days, Z_3	10 to 15 days, Z_4	15 to 20 days, Z_5	20 to 25 days, Z_6
1	0.05	0.04	0.015	0.015	0.010	--
2	--	--	.005	.005	.000	--
3	.06	.07	.015	.005	--	--
4	.07	.07	.030	.010	--	--
5	.05	.07	.015	--	.010	--
6	--	--	.020	.015	--	--
7	.10	.10	.015	.010	--	--
8	.1+	.1+	.015	.010	--	--
9	.1+	.1+	.015	--	--	--
10	.13	.13	--	.020	--	--
11	.12	.12	--	.020	--	0.015
12	.12	.13	--	.020	--	.010
13	.11	.12	.015	--	.005	--
14	.10	.11	--	--	.005	.005
15	.10	.10	--	.025	.015	--
16	.10	.10	--	.035	.030	--
17	.10	.10	--	.035	.025	--
18	.07	.07	.025	.010	--	--
19	.08	.05	.050	.005	--	--
20	.08	.08	--	.030	.005	--
21	.10	.10	.14	.005	--	--
22	.08	.08	.005	.005	--	--
23	.10	.10	.060	.005	--	--
24	.07	.08	.015	.010	--	--
25	.15	.16	.040	.005	--	--

In the preliminary experiments, two methods were used for estimating the nitrogen oxide content of the samples. The first procedure corresponded very closely to that recommended in Standard Methods and is typified by results presented in Table No. 4. Later, it was found that a considerable economy of time could be effected by omitting the step involving the removal of the free ammonia and afterwards deducting the value for this quantity found independently by direct nesslerization. Results presented in Table No. 4–a indicate that a somewhat higher degree of precision is attainable when this slightly modified procedure is followed. The indication is that under the experimental conditions a considerable error was introduced by the boiling-off process. When due allowance is made for unavoidable experimental errors, the results indicate that acidification is a very effective method of preserving the nitrogen oxide content of a sample.

TABLE No. 4.—*Constancy of the nitrogen oxide content of acidified river water*

[Results in parts per million]

Sample No.	Fresh samples		Stored samples acidified				Average reading	Average deviation
	Not acidified, Z_1	Acidified, Z_2	5 to 10 days, Z_3	10 to 15 days, Z_4	15 to 20 days, Z_5	20 to 25 days, Z_6		
1				0.4	0.3		0.35	0.050
2			0.3	.3	.3		.30	[illegible]
3	0.7	0.7	.6	.7			.68	.038
4	.7	.7	.6	.6			.65	.050
5	.2	.9		.9	1.0		.75	.275
6	1.2	.6	1.0	1.2			1.00	.200
7	1.4	1.0	1.6	2.0		1.9	1.58	.304
8	1.4	1.5	1.4	1.5			1.45	.050
9	1.4	1.4		2.4	1.9		1.78	.375
10	1.2	1.4		2.0	2.6		1.80	.500
11	1.0	1.0		1.2		1.2	1.10	.100
12	1.0	.9		2.2		1.1	1.30	.450
13	1.3	.8	1.1		1.3		1.12	.175
14	1.6	1.2		1.5	2.2	1.2	1.54	.288
15	1.4	1.3		1.3	2.2	1.6	1.56	.272
16	1.4	1.3		1.4	2.4	2.2	1.74	.448
17	2.0	1.9		1.9	2.4	2.2	2.08	.176
18	1.3	1.6	1.2	1.3			1.35	.125
19	1.4	1.6	1.3	1.2			1.38	.125
20	1.4	1.4		1.0	1.4		1.30	.150
21	1.2	1.3	1.2	.8	1.2		1.14	.136
22	1.4	1.3	1.2	.6	1.2		1.14	.216
23	1.9	1.9	1.8	1.8	1.8		1.84	.048
24	1.5	1.2	1.2	1.4	1.2		1.30	.120
25	2.6	1.3	2.0	2.2	1.8		1.98	.344
Average								0.20

TABLE No. 4-a.—*Constancy of the nitrogen oxide content of acidified river water (using the slightly modified reduction method)*

[Results in parts per million]

Sample No.	Fresh samples, Z_1	Acidified samples stored for 40 days				Average reading	Average deviation
		Z_2	Z_3	Z_4	Z_5		
26	1.5	1.4	1.3	1.6	1.6	1.48	0.104
27	.1	.4	.4	.7	.7	.46	.192
28	.5	.5	.3	.4	.4	.43	.076
29	.55	.4	.4	.45	.55	.47	.064
30	1.0	.9	.9	1.2	1.2	1.04	.132
31	1.25	1.25	.9	1.2	1.2	1.16	.104
32	1.45	1.6	1.2	1.3	1.3	1.37	.124
33	1.25	1.6	1.1	1.4	1.5	1.37	.156
34	1.5	1.85	1.45	1.55	1.65	1.60	.120
35	1.55	1.85	1.05	1.55	1.55	1.51	.184
36	1.65	2.1	1.2	1.7	1.7	1.67	.196
37	1.7	1.85	1.55	1.85	1.75	1.74	.092
38	1.55	1.7	1.3	1.8	1.8	1.63	.164
39	1.55	1.65	1.35	1.75	1.85	1.63	.144
40	1.2	.9	1.0	1.1	1.1	1.06	.088
41	1.15	.9	1.0	1.2	1.2	1.09	.112
42	1.35	1.05	.95	1.1	1.15	1.12	.104
43	1.35	1.10	1.00	1.15	1.30	1.18	.116
44	2.15	1.65	1.45	1.65	1.55	1.69	.184
45	1.6	1.5	1.4	1.5	1.6	1.52	.064
46	.9	.5	.9	.9	1.0	.84	.136
Average							0.13

The results presented in Table No. 5 indicate that the Kjeldahl nitrogen content of acidified samples is sensibly constant over prolonged periods of time. While the decrease noted in some cases, as in sample No. 16, might be taken as evidence of failure, the increase noted in other samples, as in sample No. 5, is not readily explainable other than as a variation due to analytical error or to the inherent limitations of the method. In the great majority of cases, however, the agreement is excellent and, on the whole, it may be safely stated that acidification is an effective means of stabilizing the Kjeldahl nitrogen content of a sample. Similar remarks are applicable to the permanganate oxygen consumed results given in Table No. 6.

TABLE No. 5.—*Constancy of the Kjeldahl nitrogen content of acidified river samples (using the method of direct nesslerization)*

[Results in parts per million]

Sample No.	Fresh samples		Stored samples, acidified			
	Not acidified, Z_1	Acidified, Z_2	5 to 10 days, Z_3	10 to 15 days, Z_4	15 to 20 days, Z_5	20 to 25 days, Z_6
1	3.6	3.6	2.6	3.2	3.4	....
2	3.4	3.6	3.0	3.2	3.2	....
3	3.4	2.0	3.2	3.2	....	....
4	3.6	3.2	3.2	3.8	....	....
5	2.4	2.4	....	3.2	2.8	3.2
6	3.2	3.0	3.4	2.4	....	3.0
7	2.4	2.6	2.6	2.8	....	....
8	2.8	2.8	3.0	2.8	....	....
9	2.6	2.6	....	2.8	2.8	....
10	2.6	2.6	....	2.8	3.0	....
11	3.2	2.0	....	3.0	....	3.1
12	2.2	3.0	....	3.0	....	3.0
13	3.2	2.6	3.0	....	3.0	....
14	2.6	2.6	....	2.7	1.8	1.8
15	3.2	3.2	....	3.0	1.6	1.8
16	4.6	4.2	....	3.2	2.4	2.2
17	3.0	2.8	....	3.0	2.4	1.8
18	3.0	2.8	2.4	2.8	....	....
19	2.4	2.4	2.0	2.2	....	....
20	2.4	2.4	....	2.0	1.8	....
21	2.2	2.0	2.2	2.0	2.2	....
22	2.0	1.8	2.0	2.0	2.0	....
23	1.8	1.8	1.8	2.0	1.8	....
24	1.8	1.6	1.8	1.8	1.8	....
25	1.6	1.8	1.6	1.8	1.6	....

TABLE No. 6.—*Constancy of the permanganate oxygen consumed value of acidified river samples*

[Results in parts per million]

Sample No.	Fresh samples		Stored samples, acidified			
	Not acidified, Z_1	Acidified, Z_2	5 to 10 days, Z_3	10 to 15 days, Z_4	15 to 20 days, Z_5	20 to 25 days, Z_6
1	3.3	3.3	3.2	3.2	3.7	------
2	4.4	4.4	3.6	3.8	4.0	------
3	4.4	4.4	4.0	4.5	------	------
4	4.0	4.0	3.8	4.0	------	------
5	4.0	3.8	------	3.7	4.5	4.2
6	4.2	4.2	3.9	4.7	------	4.5
7	4.2	4.0	4.5	4.3	------	------
8	4.7	4.7	4.8	4.8	------	------
9	4.7	4.6	------	4.3	4.4	------
10	5.1	5.0	------	4.6	4.8	------
11	4.6	4.4	------	4.5	------	4.3
12	4.5	4.5	------	4.6	------	4.3
13	4.5	4.5	4.5	------	4.6	------
14	5.4	5.3	------	------	4.6	4.4
15	5.8	5.6	------	4.4	4.4	------
16	4.6	4.7	------	------	4.1	4.3
17	4.7	4.7	------	4.8	5.0	------
18	8.6	7.9	7.8	8.0	------	------
19	5.2	5.2	5.1	5.6	------	------
20	4.9	4.9	------	4.9	5.0	------
21	4.3	4.1	4.5	4.6	4.4	------
22	5.4	5.6	5.3	5.5	5.7	------
23	4.5	4.4	4.0	4.5	4.6	------
24	4.3	4.5	4.4	4.6	4.5	------
25	5.1	5.1	4.3	4.5	4.7	------

PRECISION ATTAINABLE IN SANITARY CHEMICAL ANALYSIS

On the whole it appears that the preservation of samples by acidifying with about 1,000 parts per million of sulphuric acid is a very simple and highly effective method of procedure.

The results presented in Tables Nos. 2 to 6 may also be used for the purpose of estimating the probable error of the analytical methods themselves. Without attempting an elaborate analysis of the data, it will be simply stated that the probable error varies from 0.1 to 0.2 part per million and is very much the same for all determinations. Much greater errors undoubtedly arise due to the difficulty of securing representative samples for analysis.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
50 CENTS PER COPY
▽